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ABSTRACT

This volume presents a compilation and review of more than 400 research efforts reported in 1987, organized in such a way that studies on related topics are easy to access by practitioners or researchers. The document is organized around four major sections that reflect the process of teaching, learning, and schooling including: (1) "Learners and Learning"; (2) "Teachers and Teaching"; (3) "Curriculum and Instruction"; and (4) "Context and Settings." Each major section begins with an overview of the research summarized and a context for review, and ends with a reference list appropriate to that section. A discussion of the significance of the studies and implications for practice and future research is included in each major section. (CW)

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A SUMMARY OF RESEARCH IN
SCIENCE EDUCATION - 1987

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A SUMMARY OF RESEARCH IN SCIENCE EDUCATION - 1987

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PREFACE

The Summary of Research in Science Education series has been produced to analyze and synthesize research related to the teaching and learning of science completed during a one-year period of time. These summaries are developed in cooperation with the National Association for Research in Science Teaching. Individuals identified by the NARST Research Committee work with staff of the ERIC Clearinghouse for Science, Mathematics, and Environmental Education to review, evaluate, analyze, and report research results. The purpose of the summaries is to provide research information for practitioners and development personnel, ideas for future research, as well as an indication of trends in science education research.

Readers comments and suggestions for the series are invited.

Stanley L. Helgeson
Patricia E. Blosser
ERIC Clearinghouse for
Science, Mathematics, and
Environmental Education

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FORWARD

When Stan Helgeson called on July 27th to ask if I would consider writing the annual review of research in science education for the year 1987, I listened quietly to the parameters involved, asked a few questions, then requested a few days to contemplate the task. After hanging up the telephone, I swallowed hard, but it failed to remove the sudden lump in my throat. On one level the task seemed simple enough, to summarize the nearly 300 or so documents on science education filed in ERIC and other abstracts, to interpret and synthesize their results and conclusions, and to complete the work by November 1, 1988. The lump kept growing, possibly because there was no way that I could accomplish this in three months. Or possibly because I was to leave the University of Illinois at Chicago in two short days to begin my new responsibilities as Director of the Center for Science Education at Kansas State University. Or possibly because I was in the middle of writing a research grant to NSF on mole concept and stoichiometric problem solving. Or possibly because I was aware of the excellent work done on previous reviews by colleagues for whom I have the greatest respect. Or possibly because a million other reasons crossed my mind. Stan, why now?

But I knew that Stan Helgeson needed help, and he needed it quickly. He usually assigns this task in early spring, and the author(s) of the annual review are able to proceed at a more leisurely pace. But things had not worked out, and he was asking me. Now. I felt honored as well as terrified. The more I thought about the task, the more I concluded that there was but one scenario whereby I could agree to do the review. I needed lots of help, and I had an idea as to where I could get it. As the new Director of the Center for Science Education at Kansas State University, my duties are to direct and coordinate the operation of a state funded, university based center for research, curriculum and materials development, and outreach. Nearly twenty faculty members across the various colleges of Kansas State University are associated with the Center. That was where I could get help. I called Emmett Wright, the former director of the center, who is presently Head of the Division of Teacher Education at Kansas State University, described Stan Helgeson's request and its parameters, and asked him to poll the faculty in science education who are associated with the center about participating in the endeavor. Emmett called the next day to inform me that all the faculty members in science education would help. The lump began to shrink. That weekend I had lots of time to think as I drove from Chicago to Manhattan, Kansas with two cats and a load of boxes (I would return to Chicago by plane and make the same trip in six days with my wife, Pat, our two children, Amanda and Emily, and our household belongings).

Previous authors had devoted significant amounts of time to the selection of an organizational framework for the review. We had no such luxury. But a team of colleagues made the task seem not only possible, but one that would continue the trend of quality work done by previous authors. I called Stan Helgeson and accepted for our entire team. The lump was almost gone. It was time to get to work.

The first task was the selection of an organizational framework for the review. I had faced such a problem before when I edited the 1982 AETS Yearbook (Staver, 1981). In that case I had revisited the writings of Ralph Tyler and Joseph Schwab and decided to use Tyler's (1949) rationale as a framework for analysis. Now faced with a similar problem, I remembered that Schwab (1978), in a series of essays, discussed at length the concept of commonplaces and their application to the task of curriculum development. To Schwab, commonplaces were factors associated with the process of curriculum development. The entire set of factors represented a map upon which each part of the process could be located relative to other parts. For Schwab, defensible educational thought and curriculum development resulted from the consideration of four commonplaces, each equal in rank. The commonplaces themselves were the learner, the teacher, the milieu, and the subject matter. Any overpowering or intimidation by one of any or all of the others resulted in a narrow curriculum focus. Schwab believed that the coordination, not the superordination or subordination, of the learner, the teacher, the milieu, and the subject matter was the proper blend of commonplaces that produced lasting, well balanced curriculum. Moreover, he maintained that the short life of the child-centered curricula of Progressivism, the social-change-centered curricula of the 1930s, and the subject-matter-centered curricula of recent reforms were due in part to their dominance by a single commonplace. The key word is coordination. In summary, when curriculum moves into action through the act of teaching, one person (the teacher) teaches another person (the learner) something (a subject matter) within a context (a milieu). A curriculum developed by coordinating the aspects of all four commonplaces was, according to Schwab, one that could stand the test of time, unlike the aforementioned bandwagon curricula that represented dominance by a single factor.

Other scholars have utilized Schwab's notion of commonplaces in their own writings. For example, Lanier and Little (1986) organized their chapter on research in teacher education in the Handbook of Research on Teaching, (Wittrock, 1986) around the commonplaces of teacher, student, curriculum, and milieu. Similarly, Shymansky and Kyle (1988), the authors of the 1986 summary of research in science education, acknowledged Wittrock (1986) and Joyce and Weil (1986) as key in their organizational scheme which included teaching and the teacher, learning and the learner, curriculum and instruction, and instrument development and analysis. In turn, I acknowledge each of these scholars in helping me to decide upon the four commonplaces of the present review of research in science education: (1) Learners and learning; (2) teachers and teaching; (3) curriculum and instruction; and (4) contexts and settings. Schwab's apparently absent commonplace, the subject matter, is, of course, spread throughout, as it is research on science learning, science teaching, science curriculum and instruction, and science contexts and settings that is reviewed.

The second task involved decisions as to what should be included in the review. Our writing team held the view that three major sources should be represented: (1) Research catalogued in the ERIC system; (2) research published in journals; and (3) dissertations and theses filed in Dissertation Abstracts International. Much of the research cited in this review qualified on two counts, as it was published in journals monitored by ERIC; the remaining research was reviewed because it was filed in one of the sources.

Associated with the task of inclusion was that of exclusion. The proceedings of conferences relevant to science education were found in the ERIC system. The proceedings themselves were acknowledged; however, the individual papers and/or presentations were not. Exceptions occurred when an individual paper was catalogued in the ERIC system. We trust that those papers of highest quality will be published in appropriate journals, thereby justifying their inclusion in future reviews of the research in science education. Examples of such conference proceedings included the following: (1) National Association for Research in Science Teaching, Washington, D.C., April 23-25, 1987; (2) Second International Seminar on Misconceptions and Educational Strategies in Science and Mathematics, Ithaca, New York, July 26-29, 1987; and (3) International Conference on Physics Education, Nanjing, China, August 31-September 5, 1986. Also excluded were analyses and critiques of published research in Investigations in Science Education. In this instance, the original research was already published and reviewed in an earlier edition of this annual review. Readers who wish to examine the analyses and critiques should obtain volume 13 of Investigations in Science Education (Blosser and Helgeson, 1987).

The third task focused on the assignment of each research report to a single commonplace. Each contribution to the literature was surveyed and assigned to one of the four above mentioned commonplaces by at least two members of the writing team. Most fitted well into one place; however, some contained more than one major emphasis and thereby could have been placed in more than one category. Nevertheless, we assigned them to only one commonplace. Also, we decided to have a single reference list at the end of the review. In order to facilitate the inquiries of readers, we created an alphabetical index of authors and keyed the number of the section in which research by each author was reviewed to the names of authors.

The fourth task involved the assignment of members of the writing team to review and interpret the research in a particular commonplace and to write a first draft. This was accomplished easily, as the range of scholarly interests of authors aligned well with the different commonplaces. Production of first drafts was followed by my initial editing and suggestions for revision, then the production of revised drafts with later editing and revisions done by the entire writing team. In the end, each of my co-authors made an equal contribution to the writing, editing, and revising of this review; thus, they were listed in alphabetical order.

The format of the review follows a repeating pattern. Each commonplace begins with an introductory paragraph which sets the stage for the studies reviewed therein. Discussions of the studies reviewed, their concordance or divergence from the existing body of research, and implications for practice and future research occur at the conclusion of each section and at the end of the commonplace itself.

John R. Staver

A Summary of Research in Science Education — 1987

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1.0 LEARNERS AND LEARNING

We begin our Review of Research in Science Education - 1987 with a focus on learners and learning. We have chosen this commonplace first because learners are at the center of our enterprise. Moreover, according to Linn (1987), interdisciplinary research has resulted in the recent emergence of several research themes in science education. One of these themes is represented in a growing consensus of the nature of the learner. Presently, broad-based agreement exists that learners actively construct their own world views based on the interactions of their minds with the world outside through observation and experience. Thus, learners must respond to teachers, curricula, instruction, and contexts in terms of their present world views as they construct new world views. Within the commonplace of learners and learning, we have separated the research into two areas as follows: (1) concepts and reasoning; and (2) attitudes and beliefs.

1.1 Concepts and Reasoning

1.11 How do specific concepts change with age?

Four studies traced the development of understanding over a number of grade levels. Bar (1987) gave direct ratio, inverse ratio, and proportional problems to Israeli 3rd, 4th, and 5th graders in two content areas, electrical circuits and sugar in a water solution. The stages of understanding were different for the two domains. Direct ratio and inverse ratio were learned earlier than proportional ratio in the area of electrical circuits. However, in the area of sugar solutions, previous understanding helped children in the direct ratio, but made the inverse and proportion problems more difficult. **Raven** (1987) studied the use of ratios in high school science problems and found that freshmen tended to select solutions using only one variable, while juniors more often used two variables in a rule. **Dickinson** (1987) reported an attempt to map the development of children's concepts of what something is 'made of' by having children sort like objects. Improvement was found from 1st to 4th to 7th grade in the ability to correctly sort materials (e.g., to recognize powders as made of the same stuff as the bulk version of the material). Finally, **Perry and Obenauf** (1987) looked at the order of development for the concepts of movement and speed and at the relationships among task variables. Evidence was found which confirmed the work of Piaget on the development of the concept of qualitative speed.

1.12 What naive theories and misconceptions do novices bring to the study of science?

Rice and Feher (1987) studied 9- to 13-year-olds in a science museum setting to determine their naive theories about light propagation and image formation. They assigned children a series of tasks involving predictions about light traveling through a pinhole. Through interviews, they found that the children's mental model was generally one of light that traveled as a whole, carried information from the object toward the pinhole, and then to the screen. Children did not have the notion that each part of the source emitted light in all directions, a notion which was critical in predicting a wide array of images, including the inverted pinhole images.

Hastings (1987) interviewed students in grades 2, 4, and 6 in rural, suburban, and city schools about their knowledge of food as a prerequisite topic for understanding photosynthesis. The children tended to understand 'food' to be edible substances, and 'making food' to be cooking. Consequently, when they dealt with these notions in the area of animal and plant food, they brought misconceptions such as these: (1) animals planted their food or produced food products; (2) plants did not make their own food; (3) plants did not need energy; and (4) a plant's food was absorbed from outside sources. All second graders held these notions, but some of the misconceptions changed over grade levels. Older children began to see food as a source of energy for animals, and to understand how plants made food, but not how food and energy were related in plants.

Dupin and Johsua (1987) studied conceptions of electric current in French students from grade 6 to the fourth year of university. From this and previous work, they found that the naive view of electric current was the 'metaphor of moving fluid,' and that this view was mixed, partly material and partly energy. As children tried to overcome contradictions associated with their mixed view, they developed a second misconception which was particularly difficult to change, namely, that a constant current was delivered by a battery and that part of the current was used up as it traveled through a bulb. This misconception did not begin to clear up until about 10th grade, and then was not properly generalized even through university level. It was suggested that this misconception endured because it was effective in dealing with most of the electric current problems students encountered in school.

Konold (1987) looked at the reasoning patterns of undergraduates about probability by videotaping interviews in which students were asked to make predictions about an individual trial and then to show whether or not the prediction was borne out. Students often held a deterministic model which was inconsistent with probability theory but was quite reasonable in the ordinary decision making of the lay person.

Roth (1987) tried a new methodology to study naive physics reasoning in an attempt to resolve some inconsistencies in the literature regarding the abilities of novices to perform qualitative analyses of a problem. His method enabled him to discover details about the qualitative knowledge of novices, including their beliefs and their generalities as well as their incorrect and partially correct propositions. Among other things, Roth found that most errors were a product of misconceptions rather than of faulty reasoning, that novices held some contradictory conceptions, and that novices did not have the same strength of belief for all propositions.

We again call readers' attention to the Proceedings of the Second International Seminar on Misconceptions and Educational Strategies in Science and Mathematics. Many studies deal with misconceptions.

1.13 What distinguishes successful from unsuccessful students?

Lawson (1987) classified 100 high school students as concrete operational or formal operational, and tested whether these two groups could understand reasoning-to-contradiction arguments. Students were tested before, immediately after, and one month after an introduction to this type of argument. Most concrete operational students were unable to deal with this type of reasoning, either immediate or delayed, while most formal operational students were able to comprehend it under both conditions. The author argued that reasoning competence might be more critical in logical performance than content and recommended instruction in reasoning.

Krajcik and Haney (1987) reported a study in which they identified test items on a nationally standardized chemistry test that discriminated between formal and non-formal operational students and explored the reasoning patterns required by these items. The research also assessed which reasoning patterns were necessary for success in high school chemistry. Lawson's Classroom Test of Formal Reasoning was used to classify students into formal and non-formal types. The 1981 edition of the American Chemical Society-National Science Teachers Association High School Chemistry Achievement Examination (the ACS exam) was used to measure achievement in high school chemistry. The 170 subjects were students from a private, all-male, college preparatory school in Wisconsin. Results showed that two students were classified as concrete operational, 42 as traditional, and 126 as formal operational. Analysis showed that 18 (58%) of the 31 discriminators required the use of proportional reasoning; however, only three (6%) of the 49 nondiscriminators required this form of reasoning. Of the 13 remaining discriminators, six required the recall and application of a functional relationship. Of the remaining nondiscriminating items, a majority required the recall of factual information and often its application to a given situation. The sharp contrast between the percentage of discriminators and nondiscriminators that required proportional reasoning suggested that the ability to apply proportional reasoning patterns was a major factor that differentiated the ACS exam performance of students classified as concrete, transitional, or formal operational according to their scores on Lawson's Classroom Test of Formal Reasoning. This study furnished evidence that students who could use formal operational reasoning patterns were capable of a greater degree of achievement in high school chemistry than students who could not use these reasoning patterns.

Stringfield (1987) categorized high school students as concrete, transitional, or formal operational, and examined the effects on each group of computer- vs. print-presented lessons. The only significant differences in achievement were among reasoning ability groups.

Kotran (1987) assessed the developmental level and cognitive performance of 9th grade biology students and found a significant relationship between them. Students at the four developmental levels profited differentially from the instruction and utilized different mental operations.

Anamuah-Mensah, Erickson, and Gaskell (1987) found that 12th grade chemistry students who solved volumetric analysis problems by algorithm without understanding were not influenced by proportional reasoning strategies, while those who used the algorithm with understanding did make use of these strategies.

Lavoie (1987) studied prediction behaviors of high school biology students as they used a computer simulation program about water pollution. Students were categorized into concrete and formal operational, and their interviews were coded and compared. Successful students systematically manipulated independent variables, took notes, and correctly identified independent and dependent variable relationships; they also had high initial knowledge of biology and were formal thinkers. Unsuccessful students lacked motivation and persistence and were not systematic. Also, they were more often concrete thinkers and had low initial knowledge of the subject matter.

In a study of Venezuelan science students by **Niaz** (1987), success in chemistry, biology, and mathematics was predicted by formal operational reasoning ability, memory, and field independence.

In a study by **Runco, Okuda, and Hwang** (1987), two measures of creativity, the How Do You Think Test and the Teachers' Evaluation of Students' Creativity, were found to be predictors of success in a high school science program for talented students offered at The University of Hawaii.

Tan (1987) added another level of analysis to the discussion of understanding in science and what might make students successful by raising the question of what high school students mean by understanding. Four conceptions of understanding by these students were described as follows: (1) relating new physics knowledge to knowledge of the world outside the physics classroom; (2) being able to solve successfully physics problems in the physics classroom; (3) relating new physics knowledge to other experiential knowledge inside the classroom; and (4) being able to use classroom physics knowledge to explain a wide range of experiences in the real world.

Swamy (1987) reported that 97% of a group of college chemistry students solved three gas problems correctly, but only 3% had a good understanding of gas pressure, as determined from interviews. Misconceptions held by most of these students included equating temperature with heat and a molecular view of kinetic energy. Those who performed well understood gas pressure theoretically as well as empirically, while poor performers showed understanding only of the empirical relationships.

Robertson (1987) analyzed think-aloud reports of college physics students to determine whether they had a connection between Newton's Second Law and the concept of 'systems' relating to that equation. Students tended not to make the connection, but those who understood the connection tended to perform well on a transfer test.

Smith and Waterman (1987) examined the categorizations that undergraduates made of classical genetics problems. Successful students categorized problems as similar that were solvable in similar ways.

1.14 What distinguishes experts from novices?

Four studies focused on expert-novice differences in chemistry, biochemistry, or physics, using novices from high school to medical school. A fifth study looked at the interrelationships among process skills in novices. A sixth study presented a theoretical argument on the ways that experts and novices use scientific observation.

Camacho (1987) compared the understanding of high school and college novices solving chemical equilibrium problems to those of Ph.D. students and professors. Experts used several chemical principles and related skills from other domains, better heuristics such as looking back, and usually two different methods of solution. Novices, however, generally ignored the principles involved, revealed a large number of misconceptions, and used heuristics infrequently and not very well.

Gage (1987) compared undergraduates and professors solving chemistry equilibrium problems and found that novices tried to recognize problem types and apply algorithms rather than analyze the problem systems, had difficulty visualizing the problem system, and confused amount and concentration.

Ploger (1987) gave medical student novices and biochemistry experts problems in which they were to account for the existence of an abnormal biochemical function. Experts decomposed the problems from the point of view of normal functioning and from a known pathology, while novices reasoned from the normal functioning only. Experts considered more alternatives and reasoned less quickly than did novices.

Veldhuis (1987) compared beginning undergraduate physics students, advanced undergraduate physics students, and professors on one problem solution and a sorting of problems into problem types. He found that experts categorized problems by their deep structural properties, while novices used surface structures, which were descriptive features that made unlike problems seem similar. Moreover, novices were found to be less consistent in their categorizations.

Martin (1987) compared the problem solving ability of physics and engineering students in a two year college. Twenty-six (26) engineering and 23 physics students participated in the study. Results showed a significant difference in problem solving ability in favor of the engineering students. This difference was present on engineering problems, physics problems, and overall problem solving.

Willson (1987) discussed the distinction between scientific observation as a theory-confirming activity and as a theory-building activity. Willson argued that both types of observation were central to science, but that theory-confirming observation was more often used by the expert scientist, who possessed excellent domain specific knowledge and sophisticated problem solving processes. For novices the absence of domain specific knowledge and sophisticated problem solving processes may have rendered theory-building observation more useful in instruction. Willson argued that science educators have failed to make this distinction and that instruction should emphasize the teaching of science processes.

1.15 Mental models: what differences are there between experts and novices?

These two articles might well be subsumed under one or more of the above categories. However, they are separated here because the subject of mental models is important enough to discuss separately.

Leeds (1987) interviewed undergraduate students who had completed a basic nutrition course to compare their mental models of energy metabolism to a standard model broken down into links and nodes. She found that undergraduates had information available in nodes or organized concepts, but these were not linked to other nodes in a formal schema. Novices also dealt better with nodes and links that were concrete rather than those which used formal operational thinking.

Kleinman, Griffin, and Kerner (1987) compared the mental images of beginning chemistry students for such notions as solubility, mole, and energy, to those of graduate students and expert chemists. They found that the quantity and the level of abstraction of images were greater (an expert image was more likely to be a model) at a higher level of expertise, and that images of novices tended to be simply associations with the word. All groups had all three kinds of images which included the following: (1) associations; (2) concrete images; and (3) abstract models.

1.16 What characteristics of the learner can predict success in science?

Three studies reported the relationship of spatial ability and other cognitive factors to achievement in chemistry. **Carter, LaRussa, and Bodner** (1987) reported that science, engineering, nursing, and agriculture majors who scored high on spatial ability scored significantly better in chemistry than did low spatial ability students. **Pribyl and Bodner** (1987) found that high spatial ability students performed better in organic chemistry, where problem solving skills were required and where thinking about two-dimensional models of molecules was necessary. **Chandran, Treagust, and Tobin** (1987) found that prior knowledge and formal reasoning ability were related to chemistry achievement in the lab, in calculations, and in content knowledge.

Loughner (1987) studied high school chemistry achievement and related it to visuo-spatial learning, verbal cognition, spatial cognition, and multiple choice test behavior information. She looked at predictions from three theoretical perspectives and found, among other things, that the multiple choice test answers of a student could be analyzed for cognitive meaning, and that the four independent variables were all major influences on chemistry achievement.

Blatnick (1987) studied the effects of using three-dimensional models on chemistry achievement with ninth graders. One hundred fifty-two (152) students were pretested on their educational, verbal, and spatial abilities, then randomly assigned to one of two groups. The experimental group received verbal instruction, observed teacher demonstrations with molecular models, and assembled the same models. The control group received only the verbal instruction. Results showed no significant treatment effect on higher-order cognitive skill questions, chemistry achievement, or gains in spatial ability.

Biermann and Sarinsky (1987) analyzed selected cognitive abilities and other factors associated with the performance of students in a biology preparatory course in an urban community college. Discriminant analysis showed that mathematics ability was the primary factor in passing the course. Regression analysis revealed that mathematics ability, reading ability, and the type of high school diploma accounted for 33% of the variance in the preparatory course grades. Only 16% of the students who originally enrolled in the preparatory course continued on to take and pass a follow-up course in biology. However, the preparatory course grade for this group was found to be a good predictor of the grade in a subsequent course.

Enstice (1987) examined the effect of a remedial chemistry course on the success of students in a regular general chemistry course. Eighteen (18) pairs of students were matched for their performance on the Toledo Chemistry Placement Examination, then assigned to the regular or the remedial chemistry course. All students would normally have been assigned to the remedial course. Results indicated that students who took the remedial course scored significantly higher on the Toledo Chemistry Placement Examination after the course. However, there was no significant difference between the groups in the regular chemistry course grades.

The design and content of a 'preparatory crash course' in science and mathematics for adult students was discussed in a paper by **Zoller, Ben-Chaim, and Danot** (1987). Over a period of six years, 170 students participated in one or more of the crash courses. The performance of science 'attentive' adults was compared to that of high school graduates holding science oriented matriculation certificates. Their findings suggested that unpreparedness in science could be modified through remedial crash courses, especially in those situations where highly motivated adult students were involved. They concluded that success in crash courses could lead to success in later academic science.

Harpole (1987) studied the relation of achievement in physics and chemistry with selected aspects of students, their teachers, and schools. Thirty-nine (39) physics teachers, 32 chemistry teachers, 616 physics students, and 512 chemistry students participated in the study. A combination of: (1) teacher certification in chemistry; (2) undergraduate hours in physics; (3) the percentage of students who reported an "A" high school average; and (4) a teaching load that did not include general science accounted for 48.7% of the variance in the physics achievement. With respect to chemistry achievement, 44.3% of the variance was accounted for by: (1) student participation in science focus; and (2) a teaching load that included advanced chemistry.

In a related study, **Harpole** (1987) investigated the relation of gender and learning style with achievement and laboratory skill development for high school chemistry students. Forty-one (41) high school chemistry students participated in the study. Results showed that males preferred using numbers and logic, and computing and solving quantitative problems. Males benefitted most when course work was clearly and logically organized. Females preferred situations in which they could work with and help each other. The author suggested that these differences should be taken into account in the planning of laboratory exercises.

Harty, Hamrick, Ault, and Samuel (1987) investigated middle school girls and boys to see whether there might be a difference between the genders in their concept structure interrelatedness competence (ConSIC). No significant differences were found. However, scores of males were found to be correlated with previous experience, time on task, scholastic aptitude-verbal, and scholastic aptitude-quantitative, whereas scores of females were unrelated to these variables. ConSIC was discussed as a potentially equalizing factor in the science classroom, which might both uncover cognitive structures and provide practice manipulating concepts.

Selvadurai (1987) examined the extent of transfer of learning from an introductory biology course to an advanced course in biology. Lecture sections were randomly assigned to treatment or control conditions. Students in the treatment condition were taught transfer of learning techniques as they were taught biology throughout the introductory course, whereas control students were taught only biology. Analysis of the cumulative lecture grades of students revealed a significant difference between the two groups in the means of these grades.

1.17 How can we improve the acquisition of concepts, reasoning, and other knowledge through instruction?

Blackwelder (1987) studied the effects of computer programming on logical thinking. She found that 9th graders who studied a semester of Logo programming scored significantly higher than a control group on the Test of Logical Thinking (TOLT), and that a gender difference existed within the treatment group in favor of males.

Saunders and Shepardson (1987) compared concrete and formal science instruction on the science achievement and reasoning ability of sixth graders. Four intact classes were assigned to concrete or formal treatment conditions. Students were pretested and posttested on their reasoning levels as well as in seven areas of the sixth grade science curriculum for achievement. Results suggested that significantly higher levels of achievement existed in the concrete instruction group as well as the presence of a significant gender effect favoring males.

Mpi (1987) reported a study on the effects of the mode of presentation of science objects on recall. The subjects were volunteer high school students who were assigned to groups based on their field independence/dependence. One-half of each group was randomly assigned to the models presentation or pictures presentation. Results showed that subjects who were presented models outperformed their counterparts who were presented pictures and that field independent students outperformed their field dependent counterparts. No gender effects were found.

Gabel and Enochs (1987) found that pre-service elementary teachers, particularly those with low visualization scores, often confused surface area and volume. These students benefitted considerably when volume was taught as capacity and introduced before the concepts of area and length. This made volume easier to visualize and therefore less likely to be confused with length and area.

Lord (1987) tested science majors at a junior college and found that women, who began with lower spatial ability than men, improved at a faster rate than men when mixed classes were given specially designed visuo-spatial interventions.

Lewis (1987) introduced concrete experiences into class sessions of an experimental group of 10th graders, while allowing classes to proceed as usual in the control group. For the experimental group, logical thinking scores and some process skills were found to improve significantly.

Musonda (1987) analyzed data collected over 12 years from the Audio-Tutorial Elementary Science Program. Tapes were analyzed from 21 matched pairs of first graders who either received instruction by audio-tutorial methods or no instruction. A concept-mapping was performed on the children's understanding of the structure of matter over time. Instructed children tended to hold more foundation knowledge which helped in the quality of their conceptions; the diversity and inclusiveness of their conceptions were also superior. Uninstructed children were more likely to develop misconceptions.

1.18 What tools might help to initiate novices into the cultures of science?

Lippert (1987) reported on the potential for teaching problem solving in mathematics and science with computer-based expert systems. She suggested that the construction of a knowledge base and its implementation in an expert system shell clearly showed whether students could formulate questions, perceive the logic of the relations and dependencies given in a problem, and construct procedures to connect the concepts. Only when the formal structure of the problem was perceived correctly could missing data be appreciated and surplus information draw attention to the necessary and sufficient conditions inherent in the interrelationships. Students could plot their decisions and associated rules in a tree-like format as they responded to the prompts of the shell, thereby seeing the hierarchial structure, subsumptions and branching they had built. Students could correct, expand, or erase features and retest the rulebase until they were persuaded that their representation was complete and correct. Lippert explained that it was this facility that was unique as an instructional tool, and particularly attractive since it did not depend on the immediate presence of the instructor. With this approach, students were no longer spectators in problem solving, but engineers of the solutions.

Hawkins and Pea (1987) of the Bank Street Center for Children and Technology wrote an extremely thought-provoking piece on the gap between the culture of everyday thinking which students bring into the study of science and the culture of scientific thinking which science educators hope to teach them. Science education programs did not include an adequate notion of the nature of inquiry; they were built around the idea of inquiry as the accumulation of facts rather than inquiry as coming to understand science in new ways. The child, in learning science, was socialized into the scientific community, a culture with its own problem 'niches,' standards and modes of explanation, levels of precision, and ways of communicating. In coming to understand, the child must give up an alternative way of seeing things. Recognizing science education as cross-cultural education would be an extremely exciting and fruitful way to approach the problem of teaching the inquiry process. It would add to our endeavor, for example, the notion that we would be leading a student from one culture to another on the dimension of learning new conventions of what would be sensible discourse, or what would be problematic.

These studies as a whole add to our understanding of novices who bring to a learning situation naive or everyday theories of the domain, misconceptions, incomplete and 'fragile' knowledge (**Perkins and Martin**, 1986), differing views of what it means to understand a domain, and partial and often inconsistent conceptions, held as a temporary means of grappling with contradictory evidence. In some cases it appears that overcoming one misconception is almost universally accomplished by taking up a new misconception which better explains the facts. We are reminded again that overthrowing a misconception is not only difficult, it is a constructive process that learners must accomplish for themselves. Moreover, such a process depends, at least sometimes, on the reasoning abilities of students, and the studies reported during 1987 which continue to show the influence of reasoning on successful learning.

This set of research is consistent with recent findings in expert-novice differences, confirming that novices have difficulty with all the different levels at which they need to be working. Their knowledge is new, often riddled with misconceptions, and does not readily hold together; they do not have a good framework to help them tie information together; and they do not yet know the conventions, heuristics, or even the problems of the field. Teaching for the transition from novice to expert should become a clearer task as studies like these help fill out the picture for each domain. One very promising area of research is the study of learnable mental models which may be used to help provide a visual framework to hold information together in a sensible and correct way, yet need not be complete. Such schemata would presumably help with the problem of developing links among concepts. Another type of exciting research is the development of technological cognitive tools to aid in inquiry. **Hawkins and Pea** (1987), for example, described a technological tool (under development) for bridging the gap between the two cultures, one which is expected to help create an environment for a student's conceptual change. The INQUIRE system will have a QUESTIONS module, to help students formulate questions about a problem area and examine their own knowledge about it; a NOTES module to help students gather in one place the information from diverse sources (their description sounds very much like hypertext, a system in which students can readily connect one piece of information to another in a non-linear fashion); a SCHEMES module to help organize the student's ideas about the new information collected in NOTES; and a PATTERNS module to help students describe and analyze data in graphs and tables as well as determining trends.

1.2 Attitudes and Beliefs

A great deal of research was published in 1987 that dealt with the assessment of student attitudes and beliefs. These articles are broken down into four categories as follows: (1) factors relating to interest and satisfaction in school science; (2) factors relating to continued participation in school science; (3) factors relating to achievement in school science; and (4) factors relating to understanding the nature of science and technology.

1.21 What factors relate to interest, satisfaction, and anxiety?

Obviously, interest and satisfaction are affective factors. Yet quite commonly, studies involved the use of other affective factors to examine these. For example, the relationship between teacher affect and student attitude toward science was examined by **Pogge** (1987). No relationship was found between teacher affect and student attitude, though perceptions of students with respect to their teachers and their science classes were found to be highly correlated with their attitudes toward science. Students who perceived that their teachers liked science reported more positive attitudes than students who did not have those feelings. Further, students who found their science classes to be fun and exciting and those who felt curious and successful in science had more positive attitudes toward science. Like many other studies, attitudes of students toward science were found to be higher in the lower grades.

In a similar manner, **Bishop** (1987) examined the relationship between science learning environment and attitude toward school science for students in grades 2 through 12. Perceptions of students about teacher enthusiasm, teacher fairness, teacher concern, lesson presentation, teacher effectiveness, pride of the students in the class, and other related variables were positively related to attitudes for students in all grade levels of the study. Perceptions of students with respect to self-direction, fear of failure, group work, questioning strategy, stress on safety, variety of materials, and other related variables were found to be the variables with the fewest relationships to attitudes on school science. Predictive models using the relationship of these variables to attitude toward science accounted for 32% to 63% of the variance in the model.

An examination of the discrepancy between science learning environments in rural and urban junior high schools in Taiwan was conducted by **Lin and Crawley** (1987). Their study looked at attitude differences in relation to gender, ability group, and school sociogeographic location. No differences in perception of learning environment were reported by students according to gender or ability group. Metropolitan students did report higher attitudes toward science, but they also reported higher levels of speed, friction, favoritism, difficulty, cliqueness, and competitiveness in their classes. The authors reported that learning environment differences, specifically competition, seemed to lead to higher levels of attitude toward science; they also noted that although rural school students reported interest in science careers equal to metropolitan students, rural students were probably left out of the race for these careers as a result of the learning environment differences.

Talton and Simpson (1987) demonstrated that attitudes of students toward science could be predicted by attitude toward classroom environment. The composite variable of attitude toward classroom environment contained measures of emotional climate of the science classroom, science curriculum, physical environment of the science classroom, science teacher, other students in the science classroom, and attitudes of friends toward science. The model predicted between 56% and 61% of the variance in attitude toward science.

Accounting for the satisfaction of students was also an important component of a study by **Ulanski** (1987). Reporting on a five year study of student evaluations of an introductory college physical geology course, Ulanski found that the instructor was seen as a major contributor to the overall satisfaction of the students, especially, the enthusiasm exhibited by that instructor.

Commonalities between science and environmental education were the subject of a study by **Hebert** (1987). An instrument was developed and used with 239 students in grades 5 through 12. Interest in experiential education was high among students of all grade levels. Middle grade students showed less interest in health and human welfare than did high school students. High school males showed an interest in earth science while females did not.

The effect of resequencing general science content was the subject of a study reported by **Hamrick and Harty** (1987). Using a subject pool of 203 sixth grade students, respondents were randomly assigned to one of two treatment groups. The resequenced content presented to one treatment group was produced by changing the order of the chapters of the textbook to clarify the content structure and to explicate interrelationships among concepts. Results indicated that resequencing the content produced higher levels of achievement, more positive attitudes, and greater interest in science.

Paxman (1987) examined the differences in achievement that occurred as a result of different methods of grading and returning science homework for 146 seventh grade students over a seven week period. The treatment conditions included returning the homework with grades, comments, or both. Findings did not support the idea that the treatments were effective measures of increasing student attitude or achievement. Comments or grades alone were more effective than the combination of the two, but the control group scored higher than any of the treatment groups.

The relationship of test anxiety to serum beta-endorphin was examined by **Molinaro** (1987). Pre-medical students were tested before and after taking the Medical College Admission Test (MCAT) for the degree of test anxiety, as measured by the Text Anxiety Inventory (TAI), and for levels of beta-endorphin, as measured from a blood sample. Results showed that test anxiety was reduced after the MCAT, but levels of beta-endorphin were elevated. Test anxiety was also shown to be inversely related to student grade point average. A predictor set of variables for success on the MCAT was found using items from the TAI, grade point average, and level of beta-endorphin.

1.22 What factors relate to continued participation in science?

A number of studies attempted to assess why students continue in or drop out of participation in science. These studies are largely descriptive in nature and seek to define baseline information with regard to persistence in science and the relationship of persistence to issues such as gender, race, and age of the students.

Asking the question, "Why do high school students choose chemistry?," **George, Wystrach, and Perkins** (1987) examined the decision by high school students to become chemistry majors in college. Chief among the factors reported by students was the recognition by students for their own high aptitude for chemistry. This was followed by "inspiring or encouraging high school chemistry teacher," "excited by laboratory work, etc.," and "chemistry as an entree to a career in medicine."

Gender-related values and their relationship to persistence in science was the subject of a study by **Worthley** (1987). Beginning with the knowledge that women tend to drop out of science study at a higher rate than do men, Worthley examined the hypothesis that persistence in science would occur in those persons where similarity was found between the values held by the person and the values that same person felt that a scientist would hold. The data collected from 173 undergraduates supported this hypothesis.

Cross and Beaumont investigated the effects of task intervention as a mechanism to encourage females to continue with mathematics and physical science subjects through grade 12. The project included three types of intervention: (1) subject based; (2) career based; and (3) gender stereotyping. The subjects were year nine and ten Australian females who were separately presented a series of sessions in which time was made available for discussion about careers, the value of mathematics and science, and gender stereotyping pressures in society. After a full semester of contact with intervention staff, 20 students in years nine and ten were individually interviewed. Data gathered in the interviews revealed that a high degree of awareness of the project objectives existed among the participants. The project increased their appreciation of career opportunities open to females in non-traditional fields. A majority felt that the program was a good idea, but some confusion existed as to why they were separated from the males. Eighty-one percent (81%) felt that the guest speakers and videos were useful. Feedback from these female students gave rise to a cautious hope that some would now reconsider narrow career paths that several had already contemplated.

Examining factors related to the differential level of women entering science careers was the focus of a study by **Baker** (1987). Role-specific self-concept in science and self-perception in terms of stereotyped gender characteristics were examined as primary factors. Females preferring science related careers were found to have a more masculine perception of themselves and, to a lesser degree, a more positive role-specific self concept in science.

Preference for science majors and careers among black college students was the focus of a study by **Salters, Lockard, and Stunkard** (1987). Science self-concept, presence of role models, image of the field, course counseling, attitude toward science, and high school science background were significant effects in a multiple regression model that accounted for 42% of the variance in the dependent variables.

In order to determine the level of female and minority participation in science courses, **Wavering and Watson** (1987) sent surveys to all secondary schools in the state of Arkansas. Their findings indicated that black males were over-represented in general science and physical science courses in larger schools, that females were over-represented in advanced science courses in large schools and in chemistry in small schools, and that in general black students were under-represented in college preparatory science courses.

Tobin and Garnett (1987) looked at gender-related differences with respect to participation in science activities. Using a qualitative methodology including interviews, they found evidence to support gender-related differences in engagement patterns with regard to school science.

To examine the high attrition rate of students from tertiary science courses, **Wilson** (1987) conducted research on student approaches to studying. Although the students were found to have higher levels of motivation to study and better study strategies than Australian norms, these indicators did not correlate with academic achievement.

Continued participation in science by Malaysian students was the subject of a study by **Razali** (1987). While high school chemistry teachers felt that mastery of knowledge in chemistry was the most important aspect of high school chemistry students, college instructors viewed the acquisition of traits such as study skills and strategies for learning as the most important aspect of high school chemistry.

Audiovisual presentations of women in scientific careers were created to examine the effect of depictions of women in technical careers and on motivation of females to pursue such careers in a study by **Wessels** (1987). After the treatment, females reported that women employed in scientific and technical careers did not have boring jobs, less femininity, or a lack of home life. Males reported themselves as more easily employed in scientific careers than did females. Females did not list scientific careers in their top ten career choices.

Smith (1987) reported the development of an evaluation model for a summer research apprenticeship program. The intent of the program was to increase the number of minorities pursuing careers in science and engineering. The target group was high school sophomores. A follow-up study of those students who completed the summer 1980 and 1981 programs was done to determine whether these students were enrolled in science curricula in college with the intention of pursuing a science or engineering career. Telephone interviews were conducted with 63 of 72 previous participants. Forty-five (45) students were found to be actively pursuing such careers. Discriminant analysis was used to construct predictive models. The models generated predicted participation with a success of 87% to 90%. Results indicated that current college enrollment, self ratings of mechanical ability, use of books and libraries during the program, and participation in special science programs were significantly correlated with the outcome variable.

Sparrow (1987) used the High School and Beyond (HSB) data to develop a set of predictor variables for female participation in college science courses. Using a sample of 489 females who earned an undergraduate degree prior to 1984, a set of 43 variables was initially examined for predictive power. The set was reduced to six primary variables that were significant identifiers of females majoring in science. This set included the perception that mathematics would be useful in the future, high grades in mathematics, the number of science courses taken, identifying a college science major as a high school senior and as a college sophomore, and being a member of the Asian race.

Oliver (1987) examined persistence in school science using junior and senior high school students throughout their high school careers. Conducting a five-year longitudinal study of students, Oliver found that science self-concept, as assessed in the 10th grade, was the most important predictor of both high achievement and continued participation in school science. A predictive discriminant analysis was used to develop a model for participation in school science which was effective with students who did not go on to study science beyond the minimum level required by law.

Deboer (1987) developed a path analysis model to determine whether cognitive motivation could be used to explain course selection patterns leading to continued participation in college chemistry for men and women. The model demonstrated the importance of belief in the ability to succeed in chemistry as a variable to predict future participation in the subject.

An intervention program to encourage the participation of females in science was conducted by **Gardner** (1987). The study included both high school and college students and involved the use of gender-free resource materials, instructional techniques, and presentations by female science-career role models. Although the discriminant function analysis was able to differentiate women in nursing, biology, and engineering, few differences in attitudes or demographic characteristics were found. The suggestion was made that intervention strategies that succeed in retaining college women in male dominated majors may be equally effective for women in non-gender dominated majors.

Kurth (1987) reviewed the literature on the factors related to the decisions of females to remain in science. The annotated bibliography that she produced covered a wide range of areas related to this topic including biological, cognitive, and attitudinal factors. Kurth summarized the findings and suggested that the role of the parents, significant others in the life of females, and extracurricular activities were of great importance in encouraging females to persist in the study of science.

1.23 What affective factors relate to achievement in science?

Achievement in chemistry by Nigerian students was examined by **Okebukola** (1987). Student participation in laboratory activities was found to be the most important factor in the relationship with achievement. In order of importance, student attitude toward chemistry as a subject, teacher attitude toward laboratory activities in chemistry, and availability of chemistry laboratory materials made significant contributions to the variance in achievement.

Examining differences in responses to test items was the subject of a study by **Linn, DeBenedictis, Delucchi, Harris, and Stage** (1987). Explanations for gender differences were hypothesized to include differential prior instruction, differential use of "I don't know" as a response, differential response to figurally presented items, and different attitudes toward science. Results showed that females were less successful on science content items than males, but were equal on items related to scientific inquiry. Females also used "I don't know" more frequently than did males. It was suggested that females should be encouraged to take more science courses, especially courses aimed at general audiences rather than pre-scientists.

Roberts, Sarigiani, and Petersen (1987) examined the relationship between self-image and achievement in science for males and females. Males were shown to exhibit a much higher relationship between self-image and achievement than females in sixth and seventh grade populations. A covariance structural model using LISREL was constructed to examine these relationships. Longitudinal follow-up of the students showed that the strength of the self-image and achievement relationship increased over time for males and decreased for females.

Schumm (1987) examined differential levels of achievement in science courses based on the structure of the course in relation to the locus of control and attribution for success of students. Students whose locus of control was internally oriented performed better in traditional course structures. When failure in the course was attributed to lack of ability, students achieved lower grades across course types. Females tended to attribute success more to effort than did males.

A sample of 2,277 grade 12 students in Israel participated in the second IEA science study by **Tamir** (1987) to examine the relationship between selected background variables and achievement in science. Background variables studied included gender, home background, prior study in science, school-related variables, and intentions. Results lead the author to make the following conclusions: (1) the highest achievement was reached in earth science and the lowest in physics; (2) two-thirds of non-science majors were females. Non-science majors achieved substantially lower than science majors and most of them left high school highly deficient in scientific literacy; (3) more males elected to major in physics and more females chose to major in biology while the ratio in chemistry was equal; (4) males achieved better than females in physics but not in biology nor in chemistry; (5) home background, attitudes towards school and science, and motivation and career expectations all were significantly related to achievement; (6) interesting patterns of effect of prior learning on achievement emerged; (7) students achieved best in their major field of study with one exception: chemistry majors achieved as well as physics majors in physics.

Haukoos and Penick (1987) reported a study of the interactions of personality and achievement in different classroom climates. Discovery learning was encouraged in one classroom and not in the other. The authors concluded that student achievement was affected by the dynamic interventions within the classrooms.

The relationship of achievement in science to type of instruction and family background was examined by **Lee** (1987). The study was designed to identify predictors of achievement of elementary school children in grades three to five. A set of predictor variables was found that accounted for 50% of the variance in achievement. Family background accounted for 9% to 13% of the variance in achievement. Previous science achievement accounted for 10% to 15% of the variance, while previous mathematics achievement accounted for 20% to 30% of the variance.

1.24 What affective factors relate to student understanding of the nature of science and technology?

Literate and non-literate Nigerians were shown to hold both scientific and traditional notions of the world by **Ogunniyi** (1987). Holding both views was evident regardless of the status of the respondent, though persons who had taken a course in the history and philosophy of science were shown to have a preference for the scientific cosmology.

As an introduction to a much larger study, **Aikenhead, Fleming, and Ryan** (1987) examined the use of various instruments and measurement techniques related to the assessment of the understanding of students about the nature of science. They concluded that measurement of these constructs using paragraph style response as opposed to the typical Likert-type response instrument could lead to fewer misunderstandings of a student's position on the nature of science. In a second part of this study, **Fleming** (1987) investigated the ability of students to distinguish science from technology. Results suggested that in a few limited examples students were quite capable of making this distinction, but generally they were not. The authors believed that students came to see the science-technology relationship as a unified 'technoscience.' In the third part of this study, **Aikenhead** (1987) uncovered beliefs of students about the nature of scientific knowledge. The findings indicated that high school graduates generally saw scientific classification schemes as epistemological, but the majority did not view scientific models in that way. Almost all students saw scientific knowledge as tentative and no students reported that the scientific method was a stepped process as it is so often defined. The authors concluded that views of students on science were very diverse but also contradictory. In the fourth part of the study, **Ryan** (1987) continued to address the issue of beliefs concerning science, technology, and society among Canadian high school students by examining scientific literacy and gender related issues in science. The findings included the following: (1) students felt that scientists were and should be concerned with the uses for their discoveries; (2) scientists should be responsible for making their discoveries public; and (3) perceptions about the ability of women to enter science careers were similar for male and female respondents.

In an attempt to expand the base of information concerning the extent to which the ideas of children about science change during the years of school, **Clough, Driver, and Wood-Robinson** (1987) conducted a longitudinal study over a two year period using 84 students who were 12 to 14 years old in the initial data collection. The students were interviewed to probe their understanding of biological and physical science concepts. One major finding was that conceptions used by the students tended to change relatively little over the period of the study in spite of science schooling to the contrary. Of those who did change conceptual frameworks, the shift was most commonly from alternative explanations to accepted explanations, though this was not always true. Recommendations for practice included capitalizing on the fact that children are active learners, encouraging students to make their ideas explicit in writing or discussion, giving children more time to think about their understanding, recognizing the reasons that children develop alternative conceptions, and evaluating the good that may come from encouraging change in their ways of thinking.

In a study that examined the view of science held by teenagers, **George** (1987) found that the students saw the role of science and the role of the scientist as the same. The notion of truth was found to be a central issue in the way that students viewed science. Moreover, this notion of truth might be related to the gender of the student giving the response.

Snively (1987) explored the relationship between the orientations, beliefs, and experiences of students during science instruction relative to the seashore. Prior to the instructional sessions concerning the ecological principles exhibited by seashore relationships, the orientation of the students toward science was evaluated. Most students were found to hold views of the ecological principles that were not in line with accepted science prior to instruction. Beliefs did become more consistent with accepted scientific concepts after instruction. Moreover, these scientifically acceptable beliefs were still in place six months later. In addition, students were able to view the seashore from a variety of orientations after instruction.

In 1987, attitudinal research examined the attitudes of students from several perspectives. Relatively little of the work studied the typical attitude change as a result of an instructional or learning style treatment. Student attitudes and interests in relation to teacher affect were the subjects of several studies. The general finding was that attitudes of students were strongly related to perceptions of the attitudes of their teachers. In short, enthusiastic teachers of science tended to have students who reported enthusiasm for science. In addition, attitudes and interests of students were found to be predictably based on classroom and school variables.

The most consistent finding concerning further participation in science was the evidence supporting the role of academic self-concept in science. Though studied under a variety of names and descriptions, the belief of a student in his or her ability to succeed in science was found to relate frequently to future participation in science. Other variables found to relate to participation in science included inspiring teachers, motivation to achieve in science, consistency between the views of science held by the respondent and scientists, gender-related differences, approaches to studying science, and presentation of material related to careers. Models designed to describe the relationship of variables to participation were being built from a wide variety of perspectives.

The relationship between affect and achievement in science has received much attention in the past. During 1987, research in this area examined issues such as type of student participation in science, academic self-concept, attribution of success, classroom climate, and family background variables. In the studies reported, all of these variables were found to be significant contributors to the variance in achievement in various populations. Gender-related differences were consistently reported in the studies including the observations that males had equal success to females on tests of scientific inquiry, males reported a stronger relationship between self-concept and achievement in science, and females tended to attribute success more to effort than did males.

Beliefs of students about and understanding of the nature of science are an areas of growing interest in the research literature of science education. Results generally indicated that the perceptions of students about science were modifiable by instruction, but that naive conceptions of science persisted despite instruction in some cases. Importantly, some studies recognized that a naive conception of science served an important purpose for the student. These 'alternative' conceptions gave students a framework from which to perceive the world. The reports generally agreed that explicit expression of these conceptions could serve as a guide to the researcher or teacher and could produce a more reliable view of the conception of science of a student than could be produced by other means.

2.0 TEACHERS AND TEACHING

Whereas learners occupy the center of our enterprise, teachers shoulder the responsibility for learners and learning. According to Linn (1987), a new view of the role of the teacher is emerging. She maintains that instruction depends on the teacher's perspective of the learner and the subject matter, then argues that teachers formulate their own views of a discipline, learners, and schools largely independent of guidance. Moreover, the new consensus of the learner suggests that general pedagogical skills cannot be applied independent of discipline centered knowledge, a position contrary to current wisdom in teacher education. Thus, teachers must understand the discipline they teach. They must have a working environment which fosters the continued development of teaching skills, of sharing ideas with colleagues, and of thinking about teaching and learning.

In focusing on the second commonplace, teachers and teaching, we examined research in 1987 with the perspective of its contribution to the development of a new view of teachers and teaching. The studies reviewed in this section deal with two general areas, methods that teachers use and characteristics of teachers, teaching, and the profession itself. Within methods, studies focus on two specific themes, effective teaching and its impediments. Within characteristics, studies center on three specific topics about teachers, their understanding of the nature of science, their concerns about research, and their professional behaviors.

2.1 Impediments to Exemplary Teaching

2.11 What factors impede the development of exemplary science teaching practices?

Widespread teaching excellence is an ideal we must continually strive to achieve. This lofty goal, however, is mitigated by numerous pragmatic considerations, many unique to given contexts. Despite the most well intended and rigorous pre-service programs of preparation, on-site classroom instructional practices often fall short of the ideals taught in on-campus methods courses. The studies discussed below address some of the impediments and persistent problems that must be overcome if progress towards excellence is to continue.

Borchardt (1987) surveyed 218 elementary teachers, who ranked the impediments to teaching science in the elementary schools. The results were then compared with a National Science Foundation (NSF) study of 1977 (**Weiss**, 1978). The present survey reported the most significant problems as follows: (1) inadequate set-up time; (2) inadequate preparation time; (3) equipment deficiencies; (4) insufficient time to teach all units of study; and (5) lack of time to develop new units. A comparison with the NSF 1977 results revealed no significant differences for 6 of the 18 primary grade (K-3) impediments and 12 of the 18 intermediate grade (4-6) impediments. Implications for addressing these persistent problems were discussed.

Tobin (1987) performed a descriptive study regarding the delineation of exemplary science teaching practices of Western Australian science and mathematics teachers. The study involved 13 science and 13 mathematics teachers from grades 1 to 12; however, two sixth grade and two high school science teachers were selected for the purpose of describing effective as well as less effective teaching strategies. The most prevalent problems identified were associated with inadequate content knowledge. Recommendations included the need to provide elementary teachers with a resident science specialist to assist efforts among them to develop and consistently exhibit more exemplary science teaching practices.

Many problems face secondary teachers attempting to promote higher order cognitive thought among students. Using a qualitative research design, **Sanford** (1987) collected data from four science classes, two junior high general science and two high school biology classes, for the purpose of comparing relative patterns of occurrence and the management of higher order tasks. The results of this study indicated that, even under ideal conditions, teachers were not consistently successful either in engaging students in or managing the engagement of higher level cognitive tasks. A salient implication was to have practicing teachers as well as teacher educators devote more direct attention to decision-making strategies regarding the management of diversified academic work.

Higher salaries continue to be reported as an impediment to the recruitment and retention of potential 'teaching oriented' undergraduate science majors. **Evans** (1987) used the instrument entitled Self-Directed Search, to identify 'teaching oriented' personality types among 98 randomly selected freshmen undergraduate students. Those identified as 'teaching oriented' also completed several author-constructed instruments to determine major concerns about the teaching profession. The results indicated the most critical concern to be low starting salaries. Other reasons given for not selecting the teaching profession were, in rank order of concern: (1) don't want to do the things teachers do each day; (2) not much job security; (3) low maximum salaries after years of work; (4) poor job availability; and (5) discouraged by family, counselors, or friends. The crucial change cited by students to alleviate their concern regarding the attractiveness of a teaching career was higher starting pay, an average starting salary of $21,693 and an average salary of $32,600 after ten years of experience beyond the baccalaureate degree.

Stronck (1987) reported a study which determined the form of district-level science coordination perceived as most satisfactory by science teachers of British Columbia. Survey results supported the need for a science coordinator in order to meet the current needs for improved science instruction. In the opinion of teachers, the loss of such coordinators in previous years had contributed seriously to the reduction of science teaching, at least in the elementary schools.

Leonard (1987) conducted a study to determine the perceptions of North Carolina elementary (K-6) public school principals about their role and participation in the science programs of their schools. The majority of those sampled were comfortable to highly satisfied with their handling of the science curriculum. Less than half (40%) provided science in-service during the past year while slightly over 50% of the sampled principals indicated the availability of local school funds for science. Science fairs had been held in over 60% of the schools, but less than 35% of the sampled principals reported use of NSF-developed curricula. Less than 50% indicated the presence of a special facility for science teaching. These principals perceived their teaching staff as comfortable with science material, primarily using the lecture/discussion method of teaching science, and teaching science for more than 30 minutes every day.

Champagne and Hornig (1987) synthesized and interpreted the significance of several issues related to science teaching, with special emphasis on science teacher quality, supply, and demand. This report was an outgrowth of the First Annual National Forum for School Science, sponsored by the American Association for the Advancement of Science (AAAS), which convened in Washington, D.C., October 10-11, 1985. The AAAS National Forum series was initiated, in part, to respond to the conclusions made by several reports and books with respect to the condition of education and teaching in the United States. The authors concluded that the issues are extremely complex; science teaching quality, embedded within our social, economic, and political system, cannot be defined since the forces that drive it are not themselves well understood. With respect to the shortage of science teachers and the potential demand for science teachers, indications were that the problem has existed for the past ten years or more and will continue to intensify as increasing retirements occur during the next ten years. Their final conclusion noted that any progress towards improving science teacher quality and towards reducing the gap between the demand for science teachers and the available/projected supply will likely be slow.

Finally, **Rollins** (1987) performed a study to assess the certified qualifications of higher mathematics and physical science teachers in the State of Utah. A review of 362 teacher credentials indicated that only five teachers did not meet the standards for Utah certification in the above disciplines.

The impediments to enhancing teacher effectiveness are well entrenched in the work place and its workers. They will be difficult to remove. Among the most prevalent and persistent problems addressed are inadequate content knowledge, inconsistency among teachers to promote higher order cognitive tasks, low teacher salaries, and the need to provide elementary teachers with an on-site science specialist to provide assistance in improving elementary science instruction.

2.2 Effective Teaching

2.21 What strategies have emerged or continue to be promoted for enhancing science teaching effectiveness?

A variety of strategies, both traditional and novel, were reported on the enhancement of teaching effectiveness in science. Three doctoral dissertations studied the use of questioning strategies, lesson plan development techniques, and willingness to implement novel curriculum programs. One additional study examined the effect of cognitive style and science instruction.

Crooks (1987) examined the development of questioning techniques for two groups of pre-service elementary science teachers. The two groups, constituted by 38 participants, enrolled in a seminar designed to promote questioning strategies. One group received videotaped and written models, whereas the second group received lectures and written models of instruction on effective questioning techniques. Upon completion of the formal seminars, each participant presented three science lessons. No significant differences were found between groups for either the number of questions asked or appropriate use of wait time; however, a significant finding was reported with respect to the use of high-level divergent and convergent questions for the group that received videotaping during their seminar course.

In a related study, **Kellogg and Leonard** (1987) investigated the use of a single classroom computer to foster the improvement of questioning techniques of teachers. Results indicated that project teachers effectively used interactive questioning techniques to supplement computer assisted instruction. Questions asked varied in terms of quantity as well as quality.

The authors concluded that teacher behaviors could be modified from a lecture role toward a facilitator role through the use of computer technology.

Demchik (1987) investigated the ability of senior pre-service elementary education majors to plan and evaluate science lessons. The 38 seniors were randomly assigned to one of two treatments. The experimental group received intensive instruction in lesson plan development and evaluation, as a supplement to formal lesson planning experiences provided in a traditional methods class context. Both groups were required to prepare and evaluate lesson planning activities within their respective methods classes. Multivariate analysis of variance was used to assess the effect of the intensive instruction as well as the potential interaction of intensive instruction with cognitive functioning (formal versus non-formal) and science experience. Results indicated that intensive instruction was a highly significant main effect variable with respect to the ability to plan and evaluate science lesson plans.

Rivers (1987) conducted a survey of earth science and physics teachers, administrators, students, and parents, to assess the teaching effectiveness of earth science and physics teachers in Virginia. The results of the survey indicated a general lack of perceived professionalism by these science teachers with respect to teaching effectiveness, renewal of certification by means of taking additional science courses, lack of use of informal modes of science instruction, and low student involvement in science laboratory activity.

Regarding the influence of coaching on the willingness of practicing elementary teachers to implement a laboratory-based science program, **Lockard** (1987) reported that teachers who were coached demonstrated a higher level of program use. He further noted that coaching had a positive influence on teacher concerns, from those related to 'self' towards those more related to the 'impact' of the program on students, as well as more positive attitudes for learning science among students of coached teachers. Attitudes among elementary teachers towards science teaching, however, did not change as a result of coaching. A follow-up study might be of interest to determine if, after formal coaching efforts have ceased, teachers continue to make use of the program, especially since no significant change in overall attitude towards science instruction was evident.

A potential insight for the lack of change in attitudes of teachers toward science was delineated by **Conwell, Helgeson, and Wachowiak** (1987) in their report on the potential mismatch between cognitive style preferences of pre-service elementary education majors with science instruction. Using the well known Myers-Briggs Type Indicator, the investigators reaffirmed that the predominant cognitive style among elementary school educators is the Sensing Feeling type. This type is in sharp contrast to the Intuitive Thinking style, which is predominant among scientists. The study consisted of 56 participants, all Sensing Feeling types, randomly assigned to one of two treatment groups. The first group of 32 participants experienced nine science activities matched to their cognitive styles, while the other group of 24 participants experienced nine science activities mismatched to their cognitive styles. Results revealed no significant differences between matched and mismatched groups in knowledge of the material presented or overall attitude toward science and toward science teaching. The authors concluded that, although it was possible to tailor science activities that were well received by students as a result of cognitive preference matching, the concept of matching cognitive style illustrated only modest insights in the present context of this study. The critical variables in making cognitive style matching a reliable and predictively valid phenomenon are yet to be identified.

The ability to predict and enhance teaching effectiveness continues to be somewhat elusive. Factors such as questioning strategies, lesson planning and reflective evaluation, wait-time, and cognitive style mismatches continue to be reported as pre-service activities possessing positive contributions toward teaching effectiveness. Although these planning and instructional elements continue to be reported as influential considerations, studies of in-service teachers seem to illustrate a continued demand for follow-up (i.e., coaching), in order to support positive attitudes toward science and as a consequence, effective science teaching. This demand appears to be of far greater frequency among elementary teachers.

2.3 Teachers and the Nature of Science

2.31 How well do teachers understand the nature of science?

If teachers are to promote an adequate understanding of the interdependent relationships among science, technology, and society, it is paramount that they possess an understanding of the nature of science and the ways that scientists go about generating new knowledge. The enhancement of this understanding is a continuing concern of science educators. Two doctoral dissertations and several other research reports considered this issue.

Mikael (1987) examined the perceptions of 29 pre-service secondary science teachers about the nature of science using the Nature of Scientific Knowledge Scale (NSKS) and the Process Orientation to Science Scale (POTSS). Entry level results, assessed prior to enrollment by students in a secondary science teaching methods course, indicated that students possessed an adequate understanding of the following NSKS subscales: (1) developmental; (2) testable; and (3) parsimonious. However, after methods course instruction that contained explicit instruction on the nature of science, gains were not uniformly significant for any of the six subscales of the NSKS. In addition, the total NSKS scores were significantly correlated with total POTSS scores, but were not significantly correlated with other study variables.

In a related study, **Blakely** (1987) explored the understanding of the nature of science among 91 middle school teachers. Data were collected using the Test of Understanding Science (TOUS) as well as a survey to assess several demographic variables. Although middle school science teachers scored higher on TOUS than their non-science counterparts, an item analysis indicated that (1) at least 25% of the science teachers failed to correctly distinguish science from technology; (2) failed to discriminate among laws, theories, and hypotheses; (3) misunderstood cooperation among scientists; (4) believed that chance and trial and error were major factors in scientific research efforts; and (5) were unclear of the overall aims of science.

Lederman and Zeidler (1987) reported a study to test the validity of the assumption that the conception of a teacher about the nature of science directly influences his or her classroom behavior. The Nature of Scientific Knowledge Scale (NSKS) was administered to 18 tenth-grade biology teachers as a pretest and a posttest to control for any changes in their conceptions during the investigation. With the exception of down time, none of the 44 classroom variables significantly differentiated between the 'high' and 'low' teachers. Thus, the data of this investigation did not support the prevalent assumption that the classroom behavior of the teacher is directly influenced by his or her conception of the nature of science. The most intriguing result of this investigation was the failure of those classroom variables specifically related to the various aspects of the nature of science to statistically differentiate between the two groups of teachers. The authors recommended a redirection in science education to promote more adequate conceptions of the nature of science in secondary schools. Further, they recommended a more balanced treatment of the history/philosophy of science and specifically targeted teaching behaviors/skills in pre-service and in-service science-teacher education to successfully promote more adequate conceptions of the nature of science among science students.

Lunetta and Cheng (1987) provided a discourse on an alternative means for examining the nature of science using the ancient Chinese concept of tai-chi. Tai-chi recognizes that although there may appear to be dualistic perspectives, one perspective considered without its counterpart loses its richer and more universal meaning and/or balance. The authors proposed that many science education issues such as theory and practice, static and dynamic, lecture and lab, content and process, etc., should be examined together as single, more comprehensive entities rather than as individual components.

A reflective summary of the relationship between science teaching and values clarification was undertaken by **Thelen** (1987). The report contained an articulate representation of the problems associated with attempts to more accurately portray science, how scientific knowledge is generated, and how classroom science instruction often fails to take cultural values into account in presenting scientific theories. The author accurately described that decision-making, intelligent conclusion-reaching, and action-taking depend on scientific investigation, the method of the investigation, and the place for scientifically-based beliefs in the domain of reason. The author concluded that the opportunity to examine scientific values, make critically reasoned judgments about them, and illustrate the process of the selection of criteria to evaluate conflicting perspectives as objectives in science education were goals of contemporary merit.

Shuell (1987) provided a reflective interpretation of the influences of cognitive psychology and conceptual change and their implications for the teaching of science. The author distinguished two components engendered by all learning from instruction, the learning in which students engage and the teaching in which educators engage. With respect to this distinction, the author discussed four areas of concern to science education: (1) the nature and role of knowledge; (2) the active, constructive nature of learning; (3) the descriptive nature of science versus the prescriptive nature of teaching; and (4) the relationship between general principles of learning and teaching. The author concluded that alternative conceptions held by students, teachers, and researchers for any task were potentially quite different from one another. Awareness of the alternative conceptions held by all parties in the teaching and learning process was important if improvements in science education as a discipline were to occur on a long-term basis.

2.32 What are teachers' thoughts and perceptions about Science-Technology-Society curricula?

Bybee (1987) reported a survey of science educators in the United States which addressed general issues related to Science-Technology-Society (STS). Responses clarified several issues within the current debate and, more importantly, provided a basis for answering some basic questions about the STS theme and science programs. According to the findings of the survey, science educators (1) ranked population growth, water resources, world hunger and food resources, air quality and atmosphere, and war technology as the most important STS issues; (2) indicated that most social problems related to science and technology would become worse by the year 2000; (3) were most knowledgeable about population growth, energy shortages, and water resources; (4) were least knowledgeable about mineral resources, war technology, hazardous substances, extinction of plants and animals, and nuclear reactors; (5) indicated that elementary and middle schools were teaching very little or nothing about STS issues; (6) pointed out that high schools and colleges were teaching some information about STS issues; (7) suggested that it was fairly important to study STS issues in elementary schools; (8) maintained that it was important to study STS issues in middle school; (9) indicated that it was very important to study STS issues in high school, college, and adult education; (10) suggested that the minimum percent of instructional time emphasizing STS issues in elementary, middle, and high schools should be 10%, 15%, and 20% respectively; (11) implied that courses in which STS issues were presented should be required of all students; (12) suggested that science and social studies aspects of STS issues should be incorporated into one course; (13) indicated that implementation of the STS theme was just beginning; and (14) pointed out that trends relative to teaching about STS issues have progressed from 'not prominent' in the late 1950s to 'moderately prominent' in the last years of this century. Bybee commented that the views of science educators in the United States supported the contention that the Science-Technology-Society theme was established in contemporary science education. Because the STS theme was a part of science education, it was clear that there were implications for curriculum and instruction, teacher education and developing public support for teaching about Science-Technology-Society in school programs.

Bybee and Bonnstetter (1987) conducted a survey of science teachers to ascertain their perceptions of global problems, policy issues, and recommendations for curriculum and instruction related to the Science-Technology-Society theme in school science programs. Their goal was to provide help to science educators confronting the task of implementing new concepts of scientific and technological literacy into school programs. Recommendations included: (1) implementation of in-service, workshop, and summer programs as well as college courses; (2) publication of theme issues in professional journals; (3) creation of an informational clearinghouse; and (4) financial support for implementation activities.

A naturalistic research design was used by **Pantone** (1987) to study the perceptions of junior high school science teachers toward the implementation of a Science-Technology-Society (STS) curriculum. The intent of this investigation was to identify and validate critical factors, using triangulation data collection methodology, occurring among 14 junior high science teachers. The foci were: (1) on-site classroom observations; (2) clinical interviews with teacher participants; and (3) a course-related documents analysis. Data analysis indicated five critical factors which all participants perceived to be important with respect to the implementation of a Science-Technology-Society curriculum as follows: (1) content concerns; (2) frustrations with student populations; (3) evaluation uncertainties; (4) discomfort with grouping; and (5) teacher role uncertainty. The author noted that until these critical factors are systematically addressed, teachers may not view a Science-Technology-Society curriculum as possessing sufficient validity to promote its implementation as a viable alternative to more traditional curricular models.

Mikael and **Blakely** (as well as **Lederman and Zeidler**) cited the need for an increased emphasis on the philosophy of science, without which, science teachers run the risk of presenting an inaccurate view of the nature of science, scientific knowledge generation, and discernment between science and technology. **Bybee** reported on the major Science-Technology-Society themes that should be integrated within instructional practice, and **Bybee and Bonnstetter** discussed a sound rationale for the inclusion of Science-Technology-Society themes in science teaching practices. However, **Pantone** noted a high degree of concern and resistance among science teachers, regarding the validity of the STS alternative. A lack of comprehensive understanding of the nature of science may well be an impediment associated with the perceptions of teachers about enhanced curricular alternatives and their willingness to adopt them, especially those that consider science teaching from a Science-Technology-Society theme. Such a position was supported in the reflective analysis performed by **Thelen**.

2.4 Research Interests

2.41 What are the research interests of elementary teachers?

Gabel, Samuel, Helgeson, McGuire, Novak, and Butzow (1987) reported the results of an in-depth survey which examined the research interests of elementary teachers. The present study was conducted as a companion to a previous effort which focused on secondary teacher research interests. The Likert-type instrument used to conduct data collection consisted of 28 items, for which an alpha reliability of 0.80 was reported. The data were dichotomized as '1' (important) and '0' (not important), which produced two groups of response categories whose frequencies could be compared. The Cochran Test was used to identify potential differences in perceptions among elementary teachers regarding the importance of 28 research topics. Significant differences were detected for the 28 items, when analyzed according to the demographic information collected. Results indicated the top five research interests were: (1) hands-on experience; (2) science content; (3) cognitive development and learning styles; (4) problem-solving; and (5) teaching strategies. The authors also indicated the potential significance of research topics selected with the least degree of frequency, which consisted of research on sex differences and science misconceptions research. The authors noted the lack of interest by elementary teachers for research on sex differences as highly disconcerting, especially since the sampled teachers were predominately women. This finding was, in addition, also reported to be the lowest priority for the previous study on secondary teacher research interests.

2.42 Should teachers be researchers, too?

Good and Smith (1987) presented the argument that science teachers should visualize themselves as researchers as well as teachers in order to improve their own teaching and their students' learning. The authors focused on research in problem solving and reviewed briefly several trends such as the information processing approach, expert-novice differences, and the use of non-standard problems to study misconceptions. Next, they discussed methods and techniques that teachers could use in the classroom to study the problem solving capabilities of their students. Included were pair problem solving, the think-aloud technique, and diagnosis of student difficulties.

Inquiry on the research interests of teachers is sorely needed. Yet, only two studies were reported during 1987. These studies indicated that the research interests of teachers were centered around classroom variables such as learning styles, problem-solving, and teaching strategies. The dearth of studies concerning research by teachers is particularly significant considering the emphasis by national science associations on bridging the gap between research and practice. Certainly involvement by teachers in research can enhance these efforts to bring what we know in line with what we do.

2.5 Professional Behaviors

2.51 What personal characteristics serve as influential determinants of professional teaching behaviors?

We consider here a wide variety of teacher characteristics relative to concerns in evaluation, curriculum, instruction, teaching environment, functional paradigms, and reading patterns. Although these studies could quite easily be subsumed under other rubrics, they are summarized here in terms of qualitative professionalism.

In noting that it is increasingly difficult to maintain currency in the wake of continuing advances in scientific and methodological practices, Koballa (1987) examined the professional reading patterns of 136 Texas middle school life science teachers. Data were collected by means of a 112-item survey, which included teacher demographics, factors affecting instruction, needs for teacher assistance, types of teaching techniques, informational sources regarding new scientific developments, and equipment/material availability. Of the 136 teachers surveyed, 46% indicated professional journals/periodicals to be very useful as sources of information concerning new developments in life science. The journal perceived by teachers as most popular was *The Science Teacher*, followed by *Science 85*, *National Geographic*, and *Science World*. Notable omissions, those journals reported as possessing poor readership, included *Science Scope* and *American Biology Teacher*. The former was noted by the author with considerable dismay, especially since it was specifically intended for the middle school science teacher. Finally, Koballa reported that no significant relationships existed between reading practices and any of the demographic variables.

Continuing on the same theme, Koballa (1987) conducted a descriptive study on the science-oriented journal reading habits of elementary teachers in central Texas. His purpose was to expand the database regarding science reading habits of teachers. A thirty-item questionnaire was designed to collect data regarding science reading habits. Items were organized into three sections: (1) teaching demographics; (2) time spent reading science journals; and (3) titles of 22 science-oriented journals. Two hundred thirty-seven (237) elementary teachers participated in the study. Of the sample, 202 were female. Eighty-seven (36.7%) reported that they typically did not read science-oriented journals. Eighty-four (35.4%) reported reading science journals from 1 to 30 minutes per week while sixteen (6.8%) reported reading them 31 to 59 minutes per week. Twenty-two (9.3%) teachers read science-oriented journals from 60 to 120 minutes per week and 28 (11.8%) read for more than 120 minutes per week. Relationships between time per week and gender, degree attainment, size of district, and teaching experience were found not to be significant. However, a significant relationship was found between time spent per week and grade level taught, with teachers of grades 4 through 6 spending more time than teachers of K through 3.

Ayers (1987) reported a study that analyzed six primary science education journals published in 1985 and compared the results with baseline data collected in 1970. This comparison indicated that the amount of material published per year during that period increased, with additional emphasis on methods of teaching.

Corcoran (1987) investigated the influence of natural history curriculum materials upon science teaching behaviors. A volunteer population of 140 teachers, who had previously responded to a survey of needs, was selected for this formative evaluation study. It was reported that teachers who had been active in out-of-doors experiences as children and who had participated in self and/or other than self conducted field trips were more likely to make use of natural history curriculum materials.

In a study of two different science teacher education programs, **Conrath** (1987) identified teacher characteristics and contextual variables that were related to attitudes toward inquiry, use of inquiry in the classroom, and use of effective classroom management strategies. The comparison groups for this study consisted of 51 full-time teachers who received teacher certification within the last five years and were graduates of one of two teacher education programs, a traditional undergraduate or a post-baccalaureate degree program. Post-degree graduates were reported to possess significantly greater positive attitudes toward inquiry and inquiry-oriented laboratory preparation. No significant differences between groups were found, however, for either effectiveness of classroom management practices or for the use of inquiry teaching behaviors.

In a closely related study, **Stalheim** (1987) surveyed 398 high school biology teachers from an eleven state region. The intent was to identify professional teacher behaviors that might be significant predictors of their use of inquiry laboratory activities. Qualitative data were collected by means of a 66-item survey questionnaire. Results indicated that inquiry teaching was more a product of the level of personal motivation possessed by an individual teacher and the strength of that teacher's curiosity about the natural world than it was the product of education and training.

Turner and Turner (1987) surveyed 158 faculty members at 36 universities in the United Kingdom to determine the emphasis placed on science education in a multicultural society as a feature in science methods courses. Forty-six (46) faculty members at 30 universities responded. Only seven universities devoted a full day or more to the issue of multiculturalism. The authors found that very few faculty members actively considered the multicultural aspects of their subjects. Many expressed the opinion that multicultural issues were important, but that they did not know how to approach them or did not have sufficient time to address them. The authors suggested that teacher training needs to emphasize the issues raised by a multicultural society.

Jungwirth (1987) tested secondary pupils, student teachers, and teachers from Israel, Australia, and South Africa to determine their critical thinking ability. Participants responded to a test that included eight categories of logical fallacies relevant to science education. Jungwirth found that most respondents either picked a logical fallacy or attended to contextual aspects of a problem instead of selecting the logically sound conclusion. The author concluded that the concept 'control of variables' was either not learned or not internalized because respondents chose plausible answers instead of testing for validity. Respondents relied heavily on personal knowledge and did not respond to logically parallel situations in similar ways. The author argued that teachers must be able to think logically and critically themselves in order to help students develop their own thinking skills. Therefore, teacher training needs to emphasize the importance and development of critical thinking skills.

Two additional studies performed an assessment of professional behaviors and teacher characteristics relative to the respective functional paradigms used by exemplary secondary biology and chemistry teachers.

To interpret why exemplary high school biology teachers and their classrooms function so successfully, **Tomkiewicz and Abegg** (1987) performed an assessment of functional paradigms of experienced teachers. A sample of 28 biology teachers, identified as outstanding teachers and possessing high degrees of professional involvement, were selected as participants. The intent was to determine commonalities that existed among these teacher participants with respect to recognized traditional role expectations of teachers: (1) teaching; (2) learning facilitation; (3) curriculum development; and (4) governance. Data were collected by means of modified clinical interview techniques supplemented by a variety of questionnaires. The authors reported functional paradigms for the following categories: (1) teacher; (2) curriculum; (3) student; and (4) governance.

Lantz and Kass (1987) performed a qualitative research study to identify the functional paradigms of secondary chemistry teachers. Observations and interviews were conducted on three teachers who were representative of a range of experience and school settings. Each school was visited five times over a four month span of time. The curriculum program ALCHEM was selected as a specific context for the study. Results indicated that although differences existed among the three teachers with respect to how they interpreted curriculum materials, the use of the functional paradigm concept in research allowed for variations in individual beliefs, values, techniques, exemplars, and routines; commonalities were far greater than differences among individual teachers. The authors also found that teachers placed a greater value on teaching theoretical chemistry and a relatively low priority value on teaching either the nature of science or Science-Technology-Society themes. Finally, the authors reported that teachers modified curriculum materials into classroom practice on the basis of pedagogical efficiency, academic rigor, and student motivational levels for which the curriculum materials were intended. Implications were reported regarding an increased awareness by curriculum developers and school administrative personnel for recognizing the functional paradigms of teachers.

Although pre-service and in-service teachers were reported to possess an adequate understanding of the nature of science, teachers at both levels not only fail to make additional gains in an understanding of the nature of science after the completion of undergraduate study, but they also seem to regress in their ability to demonstrate a comprehensive understanding of the distinctions between science and technology and the overall aims of science. Such a lack of understanding of the role of science, its philosophical premises, and consequential impacts on technology and society may be a critical factor in developing professional inquiry teaching behaviors, the reported patterns of elementary teachers' research interests, and the relatively low priority reported for teaching either the nature of science or Science-Technology-Society themes. Moreover, if we accept Linn's (1987) observations concerning the learner as an active constructor of knowledge, then we must also consider the implications that a constructivist's view of learners and learning has for teachers and teaching. At the outset of this commonplace, we noted Linn's position, that a new view of the teacher and of teaching is emerging, that this view stands in contrast to well entrenched principles of teacher education, that much of teacher education reflects the premise that general pedagogical skills can be applied independent of subject matter and knowledge. Linn argues against this premise on the grounds that specific subject matter knowledge is required and integral to effective teaching. Teachers cannot design and carry out instruction that helps learners to construct discipline-centered knowledge without having such knowledge themselves.

2.6 Professional Concerns

2.61 What are the most important professional concerns of teachers?

Barker (1986) conducted a study designed to identify major work place variables that affect job satisfaction within educational organizations and to utilize these variables to construct an intervention framework grounded in the principles of the Quality of Worklife (QWL) paradigm. The QWL variables perceived as most important were the extrinsic factors of resources, support systems, and work load. Those perceived as least important were recognition, inclusion, and growth, all intrinsically related to work place satisfaction. QWL variables viewed at a relatively high level of satisfaction were sense of achievement, resources, job enrichment and support systems. Areas of least satisfaction included growth, status, and formal rewards. Several significant relationships existed between demographic factors representing age, experience, salary, and level of education and the QWL variables of highest concern. Based upon the findings, a model was developed to integrate aspects of the QWL approach with work place satisfaction.

Smith (1987) reported a demographic profile of Tennessee secondary school science and mathematics teachers including their general levels of job-related satisfaction, future plans, perceptions of the extent to which they possessed certain skills and abilities, the values which they placed upon certain job-related variables, and their achievement in the teaching profession as well as possible relationships among the variables. As a group, the science and mathematics teachers were highly educated. Almost one-half of the teachers indicated that they would be unlikely to choose education as a career again, and 35% indicated that they anticipated leaving teaching. Teachers noted that an improvement in extrinsic factors would improve their job satisfaction. Regression analysis linked satisfaction with: (1) valuing and achieving a sense of doing well; (2) recognition from family, friends, students, administrators, and supervisors; (3) a chance to contribute to important decisions; and (4) valuing opportunities to learn. Satisfaction with teaching appeared to be linked to intrinsic rewards. These teachers rated themselves relatively low on their abilities to use computers and to analyze printouts.

Jbeily (1987) studied the needs and concerns of English-speaking public secondary physics, chemistry, and biology teachers in the five geographic regions of Lebanon. A set of three questionnaires was used to conduct the study, a demographic questionnaire, a modified version of Moore Assessment Profile (MAP), and an instrument based on the Concerns-Based Adoption

Model (CBAM). All teachers reported many high priority in-service needs. All teachers had mostly medium level task concerns involving issues related to management, efficiency, organization, scheduling, time demands, adequacy of curricula, and availability of instructional materials and laboratory equipment. All had high level impacts concerns involving issues related to the impact of teaching on the performance and competence of students, and changes needed to increase student outcomes.

Gremli (1986) conducted a case study which examined the implementation of a new inquiry-based, guided discovery science curriculum in Singapore lower secondary schools and the resulting changes in teacher and student roles and role relationships. Gremli found little evidence of change during the first year the program was implemented. This lack of role change appeared to be linked with teacher perceived constraints through which they rationalized their teaching role together with large class sizes, students' limited command of English, and the meritocratic nature of the education system as a whole. Potential for change was further constrained by the fact that the curriculum materials were not entirely consistent with the purported goals of the program. Furthermore, inquiry teaching behaviors were neither adequately explained nor appropriately modeled in the teacher in-service experience. The results suggested that established role relationships were indigenous to the research setting and were unaltered by the implementation of the new program. Moreover, they served to maintain existing patterns of role and role relationships, rendering the kinds of changes anticipated by the curriculum developers very difficult to achieve.

2.62 What are teachers doing in the classroom?

Gallagher and Tobin (1987) investigated the activities and interactions of teachers and students in two Western Australian high schools. This ethnographic study examined activity structures, reward systems, teacher expectations, and disruptive students. It also examined contrasting managerial styles of three teachers. The authors derived several conclusions as follows: (1) secondary science teachers equated task completion with student learning; (2) a majority of class time was devoted to whole-class instruction during which the pace of instruction depended on the responses of 5-7 more able students; (3) teachers held different expectations of their students during class work and laboratory work; (4) the level of cognitive demand placed on students during science classes and labs tended to be relatively low; (5) students with poor achievement and motivation frequently were problematic to secondary science teachers who offered watered-down versions of regular classes to them; (6) disruptive behavior often appeared to occur when the cognitive demand of tasks exceeded the capabilities of students to respond; and (7) preparation for examinations was continually reinforced by teachers as the purpose of instruction, class work, homework, and lab work.

Working on the premise that a lack of a clear role definition limits the effectiveness of the science supervisor position and that any given role in an organization is perceived differently by different groups or individuals, **Madrazo and Hounshell** (1987) analyzed the role expectancy of the science supervisor in North Carolina public school systems as perceived by superintendents, principals, elementary teachers, secondary science teachers, college science educators, and supervisors themselves. Results indicated significant divergence in role definition for the science supervisor, especially concerning evaluation functions. The authors recommended that science supervisors should examine carefully the role expectations of the various groups of individuals in their school systems. A clear definition of the requirements and role description for the position should serve as a basis for the training of supervisors in general and science supervisors in particular. It was also recommended that the role function of the science supervisor undergo continuous evaluation. Only through reassessment of the role expectancy of the various groups involved will science supervisors and other educational leaders keep abreast of changing attitudes and perceptions concerning their roles.

Searles and Kudeki (1987) reported a study that determined the level of agreement between principals and teachers when using established criteria to measure the effectiveness of a science teacher. Results indicated that participating high school principals and science teachers agreed on the relative importance for most evaluative criteria. Using these results, the author constructed a profile of the attributes of an outstanding science teacher, and made recommendations to school board officials, school principals, science teachers, and researchers in the field of education.

Affannato (1987) conducted a survey of high school biology teachers in public and private schools to determine their opinions about the teaching of evolutionary theory and/or the creation model. Results showed that the religious preferences of the respondents influenced their opinions more than did their educational preparation. Most respondents indicated that the specific content of a biology course should be determined by biology teachers, not by federal or state legislative bodies.

Bush (1987) examined the relationships between teacher characteristics and science achievement for seventh grade teachers in selected small South Carolina schools. Data concerning the certification and education level of teachers were compared with the mean normal curve equivalent score gain in science on the Comprehensive Tests of Basic Skills (CTBS) from grades 4 to 7. Analysis indicated no significant relationships between any teacher characteristics and science achievement on the CTBS.

Boyes (1987) reported an analysis of teacher interest in science and mathematics recertification programs. The results showed that 26.4% of the teachers studied were interested in science and/or mathematics recertification programs. However, most of these potential recertification candidates were not interested in pursuing recertification programs based on existing school district contractual/policy decisions. Among the alternatives presented, teachers were most interested in assignment guarantees and full-time paid leave for study. In terms of program design features, potential candidates preferred college-based courses and a full tuition waiver or subsidy. The most frequently cited reason for interest was job security.

Initial and perhaps idealistic satisfaction with teaching as a profession is certainly related to intrinsic rewards; however, as both **Barker** and **Smith** indicated, a maintenance of long term satisfaction among experienced teachers depends largely upon the need to perceive eventual extrinsic rewards as complements to intrinsic reinforcers. Both authors noted that teachers desire more opportunities to contribute to the overall decision-making process in schools. Their findings are consistent with the conclusions of several national reform groups, which were reported earlier in this decade. As a result of the diminishing importance of intrinsic satisfaction among experienced teachers, perhaps the conclusions drawn by **Gallagher and Tobin** should not be surprising. The fact that teachers equate task completion with student learning, instruction with test readiness, and a predominance of whole-class instruction, seems to be symptomatic of a sense of loss of idealism. Thus, without extrinsic complements, many experienced teachers may begin to treat teaching more as simply a job and less as a professional career.

2.7 Pre-service Teacher Education

Several studies were reported in 1987 which dealt with the preparation of teachers. The topics and questions range from evaluations of teacher education programs to the abilities of pre-service teachers to deal with specific misconceptions. We focus first on studies of pre-service teacher education.

2.71 Can standardized test scores predict success in student teaching?

Olstad, Beal, and Marrett (1987) investigated criteria currently used for admission and exit standards in student teaching in order to identify effective predictors for student teaching success. The authors examined grade point average, California Achievement Test of Basic Skills - total score, and the National Teachers Exam Specialty Tests for chemistry, physics, general science, and biology in order to predict student teaching competence as measured by a performance based assessment. The results confirmed previous research in that standardized test scores were not effective predictors of student teaching success.

2.72 What knowledge, skills, and attitudes are important for pre-service teachers?

Strawitz and Malone (1987) examined the acquisition and retention of integrated process skills of pre-service elementary teachers. The purpose of their study was to compare the effects of two methods of instruction, teacher-directed and self-instructional, designed to teach prospective elementary teachers to acquire and retain integrated science process skills. Thirty-two (32) female students were randomly assigned to one of two sections of an undergraduate science methods course. Instruction was provided by the teacher in the teacher-directed section, whereas instruction was provided by written self-paced, self-instructional materials in the self-instructional section. The Test of Integrated Process Skills (TIPS) was used to measure the acquisition and selection of integrated process skills. Results indicated that the self-instructional method was significantly more effective than the teacher-directed method. No breakdown of the individual process skills was presented.

Zeitoun (1987) examined the competencies of pre-service Egyptian biology teachers in identifying and correcting misconceptions about photosynthesis. His purpose was to search for relationships between each competency and background knowledge, field independent/dependent cognitive style, and previous experience of scoring student assignments or tests; and to select the best predictors of each competency. Two hundred (200) were selected from a pool of prospective teachers enrolled in two colleges of education in Egypt. A study-specific instrument was developed to assess misconceptions about photosynthesis. The findings of this study implied that teacher training programs should increase pre-service teacher competencies in diagnosing and correcting misconceptions of students.

In another study involving pre-service elementary education majors, **Hunn** (1987) investigated the comparison between self-concept in science teaching and the type of science methods course taught. Central to this study was the development and partial validation of the Self-concept in Science Teaching Scale. A test-retest reliability of 0.94 and content validity with Scott's coefficient of interrater reliability of 0.73 were found. Students in a field-based science methods course and a traditional science methods course completed measurements of self-concept in science teaching, general self-concept, locus of control, and achievement in science. Additional academic data included total hours completed, total hours in science completed, total grade point average, science grade point average, and an achievement test for the 100 subjects. Findings included strong relationships favoring the traditional methods group on the variables of locus of control, total hours of credit, and total hours of science. The author also reported significant differences among levels of self-concept in science teaching, general self-concept, total grade point average, science grade point average, and science achievement test. Factor analysis of the items on the newly developed self-concept in science teaching scale yielded three distinct factors: (1) general self-concept; (2) quantification; and (3) memorizing. A step-wise multiple regression analysis predicted several contributors to the self-concept in science teaching score, including general self-concept, grade point average in science, methods course achievement, and locus of control. The study indicated that self-concept in science teaching was a worthwhile and measurable construct.

The effect of an activity-based model on the reduction of science teaching anxiety was the subject of a study by **Goldsmith** (1987). This study introduced a structured teaching unit consisting of eight hands-on activities to determine if breaking down general concepts such as 'the scientific method' into smaller units to be taught through process skill activities would lower the anxiety of pre-service elementary teachers toward teaching such material. Also, the author attempted to characterize developmental antecedents by relating science teaching anxiety with Type A behavior patterns. Two sections of a science methods course were divided into experimental and control groups. Four weeks of activities were presented to the experimental group, while the control group received usual instruction. Results indicated that anxiety towards teaching science was positively and significantly reduced in the experimental group. Further, Type A behavior pattern had no association with anxiety in this study.

Okeagu (1987) studied the effects of a science methods course, including its field experience, on the attitudes, concerns, and anxiety of pre-service elementary teachers toward teaching science. The purpose of this study was to evaluate a science methods course as presently structured in terms of effectiveness in producing a shift toward more desirable affective responses. The impact of the entire course, changes in the order of component parts, and inclusion of a field experience were examined. The subjects of this study were pre-service elementary students in their third undergraduate year. All were females enrolled in science (two experimental groups) or mathematics (the control group) methods courses. Findings indicated that the field experience component of the science methods course did not significantly affect the attitude toward, concerns, and anxiety about teaching science. Also, the instructional phase of the course made a significant difference on the impact of the concerns of the subjects. No significant difference was found between the experimental and control groupsin terms of attitude toward, concerns, and anxiety about science teaching. Finally, placement of field experience at the beginning or end of the science methods course did not produce a significant difference.

A study by **Anees** (1987) focused on a meta-analysis and partial validation of the attitudes toward science, science teaching, and understanding the nature of science for pre-service elementary teachers. A meta-analytical study of experimental literature related to attitude toward science, science teaching, and understanding the nature of science comprised phase one of this research. Studies of the last 25 years in four journals, Journal of Research in Science Teaching, Science Education, School Science and Mathematics, and Science Teacher, were used. The second phase consisted of an experimental partial validation involving pre-service elementary teachers regarding the three constructs listed above. In the meta-analysis phase, 348 citations were collected, encoded, and subjected to a series of exclusion analyses to determine common statistical denominators. This step resulted in the reduction to 188 citations. A final yield of 16 citations was then statistically treated to calculate a delta index of 0.959 (SD = 1.425). In the experimental phase, three instruments, a science attitude scale, an understanding the nature of science scale, and a study-specific pre-service elementary teacher attitudes toward science teaching scale, were administered to 71 pre-service elementary teachers who were exposed to three different instructional sequences as follows: (1) Science Process-Content Methods-Field; (2) Science Process-Methods; and (3) Methods. Findings indicated that field experiences had little influence on students' attitudes toward science teaching. The three groups were significantly different with respect to their understanding of the nature of science. No significant differences were found in terms of attitudes toward science and attitudes toward science teaching.

2.73 What are the strengths and weaknesses of teacher education programs and their faculties?

An evaluation of the science teacher education program at the University of Iowa was conducted by **Krajcik** (1987). As one part of this longitudinal study, students of 39 program graduates completed a questionnaire which measured their attitudes toward science teachers, science classes, and the study of science. Analysis of additional attitudinal data from 2,871 students indicated both favorable and unfavorable results. For example, 89% of the students perceived their teacher as asking questions and 80% perceived their teacher as letting them ask questions. However, only 32% of the students perceived their teachers as taking personal interest in them. In another part of the study, 30 program graduates completed the 1985 National Survey of Science and Mathematics Education. These responses provided information on objectives, teaching strategies, equipment use, time allocation, and text use. Responses were compared to a select national sample of teachers invited to NSF-funded Honors Workshops in 1985. Analysis of the responses indicated that both Iowa graduates and Honors Workshop teachers had similar course objectives and teaching strategies, used materials and equipment for a similar amount of time, and allocated class time in similar ways.

An ethnographic study designed for program evaluation was conducted by **Perkins** (1987). The program was non-traditional in that it integrated knowledge and skills from a variety of academic areas, including communications, field biology, and natural resource management. Analysis of the participant observational data was done in terms of program goals and issues surrounding the teaching and study of science. Thirty-six students participated in the study. Results indicated that while the program planners intended to provide an integrated curriculum, there were several shortcomings. These included a lack of consideration for the complex nature of integrating curriculum on the part of the planners, minimal cooperation between program faculty, minimal coordination between courses, faculty did not prepare students to analyze and synthesize information, little direct help from faculty to help students, and a lack of faculty commitment to the integrated nature of the program.

Professional preparation and responsibilities of pre-service elementary science methods faculty were examined by **Barrow** (1987). The author collected data concerning the professional preparation, related work load responsibilities, elementary teaching experience, as well as demographic information about each faculty member. A 77-item questionnaire was designed and reviewed by 3 elementary science education faculty to determine validity. Instruments were mailed directly to 91 elementary science methods instructors from 81 institutions in 6 New England states. Fourteen institutions did not offer elementary science methods and were dropped from the study. After a follow-up letter, a return of 59% was obtained. Findings indicated that larger institutions had the highest percentage of trained science education faculty (75%). Moreover, 14% had taken nine or less hours in science content. The majority of the respondents had elementary teaching experience. In terms of gender, 33% were female and 67% male. Mean age was 46.9 years, and 61% had obtained a terminal degree. In terms of course load, 54% taught one section of elementary science methods per year; 11% taught three or more such courses. Only 33% had published an article within the last two years.

In a related endeavor, **Barrow** (1987) gathered demographic data about New England teacher education institutions and their programs. Specifically, data were collected about the amounts and types of science content, science processes and methods, science teaching techniques, effectiveness, of science preparation and general preparation as an elementary science teacher. A 28-item survey was mailed to all 97 teacher education institutions in New England. There was a 83% return rate on the survey. Almost 50% of the responding institutions were private, with 19% being church affiliated. The results underscored the fact that New England pre-service preparation were generally inferior to programs in the 50 largest teacher education programs across the nation. For example, 26% of New England institutions did not require the completion of methods in science courses. However, New England programs provided greater options in the choice of science courses for students.

Barrow (1987) also gave a descriptive report of science teacher education programs in New England. He reported that most institutions were not meeting NSTA or NCATE standards for science teacher preparation, but most administrators claimed to have excellent or good preparation programs. Other findings suggested a future shortage of science teachers, especially in the area of chemistry and physics. Last, the results indicated that science teachers were not being trained in the area of Science-Technology-Society.

Prather and Shrum (1987) discussed the need for an increased emphasis on science education for out-of-school adults. They presented a historical overview of the change in the nature of the American work force and examined problems to be encountered in the preparation of science teachers to fill this anticipated demand.

In response to an alarming trend toward emergency and temporary certification practices and critical shortages of qualified prospective science teachers, **Moore** (1987) provided a reflective analysis comparing traditional and enhanced programs of preparation for teaching science. To enhance the quality of science teacher preparation, Moore (1987) made several suggestions, as follows: (1) develop a nationally recognized certification program for science teachers; (2) promote the establishment of science teacher education as a five-year program resulting in a Master's degree upon its completion; (3) develop more stringent criteria for admission to the teaching profession at the undergraduate level; (4) establish greater cooperation and articulation between higher education and public school science teachers; and (5) utilize multiple evaluation techniques to assess science teacher competence throughout undergraduate experiences. Many of the above suggestions were consistent with policies adopted by the National Science Teachers Association, parameters promoted by several national reform initiatives issued earlier in this decade, and recommendations alluded to by prominent educators such as Goodlad (1984). The author concluded that such a search for excellence must be viewed as more than a passing fad and called for the return of a general respect for the profession of teaching with specific reference to science teaching.

Research on pre-service teacher education included investigations on student teaching, affective attributes, and pre-service programs. Only one study involving student teaching was reported. This study confirmed that standardized test scores are not effective predictors of student teaching success. Studies involving knowledge, skills, and attitudes of pre-service teachers suggested that field experiences had no effect on pre-service teachers in terms of attitude toward science, science anxiety, or science teaching. These studies are both confirmed and disputed by previous research. Another study developed and validated an instrument to measure science self concept. Results indicate that this instrument will be an important contribution to pre-service science teaching research. Reduced anxiety in pre-service science teachers was the target of another study. In this investigation, activity-based science instruction reduced science teaching anxiety. Finally, several studies were conducted involving pre-service science programs. In one study science education graduates were compared with a national sample of honors workshop participants. No major differences were found. Professional preparation of science education faculty and teacher education programs in science education were the targets of two studies in New England. Most results of these studies were not surprising. Many faculty (40%) did not have a terminal degree and only 33% had published. Generally, most institutions were not meeting prescribed standards. These studies were restricted to the northeast and should not be considered generalizable to other areas.

2.8 In-service Teacher Education

The continuing education of practicing teachers was the subject of several studies during 1987. Topics ranged from the organization and evaluation of staff development workshops to the needs of teachers concerning professional development. We begin with a focus on evaluation.

2.81 What effects are observed in staff development programs?

Staff development and science teaching was the subject of a study by **Bowyer, Ponzio, and Lundholm** (1987). The purpose of the research was to focus on staff development delivery variables in the context of science teacher workshops. Specifically, the authors studied the effects of variations in workshop design on science teachers' intentions to use the new ideas in their classrooms and effects of sponsorship and leadership variables on the selection of staff development workshop designs. The theoretical framework for staff development used in this study was based on Piaget's work on the development of logical thinking in adolescents. Written staff development materials used to communicate these concepts were taken from **Karplus, Lawson, Wollman, Appel, Bernoff, Howe, Rusch, and Sullivan** (1977). Results suggested that 8 to 16 hours was a minimum amount of time spent in workshops for staff developers to consider if teachers were likely to use the content in their classrooms. The workshop design option providing opportunity between workshop sessions did not differentially affect teachers' reported intentions to use the content in their classes. The authors also reported that their data suggested distinct advantages in having workshops sponsored by school districts rather than organizations. Finally, the importance of a strong, active administration to negotiate the more useful staff development options was suggested by the data.

An evaluation and analysis of a cumulative elementary science staff development program was conducted by **Stone** (1987). The purpose of this study was to examine the effects of combinations of four staff development activities that were extensions to a summer workshop in science on the confidence in and the commitment to teaching science by the workshop participants. Confidence was assessed by using the State-Trait Anxiety Inventory and commitment by using a scale from the Science Council of Canada's Questionnaire for Teachers of Science. The study involved 67 teachers from 18 schools representing 9 districts in a metropolitan area. Subjects went through a self-selection process. Activities were cumulative beginning with no activities for the first group, one for the second, two for the third, etc. The activities were: (1) attending a local science teachers conference; (2) receiving a monthly newsletter; (3) participating in team meetings each month; and (4) being observed two times by a science education expert while teaching a lesson. Results indicated that follow-up activities contributed to increased commitment to teaching science for teachers who had attended other in-service training sessions. Confidence in teaching science was seemingly not affected by follow-up activities. Years of experience were found to enhance teachers' confidence in teaching science.

Zielinski (1987) investigated the effects of two models of science in-service education on the acquisition by participants of knowledge and stages of concern profiles. In addition, the students of participating teachers were evaluated for their acquisition of knowledge. The independent variable was the mode of in-service training. One in-service program placed the participants in an active learning role while the other allowed them to be passive learners. Each mode consisted of four, 1-1/2 hour training sessions emphasizing the knowledge and skills necessary to implement a new energy science curriculum. The dependent variables included acquisition of knowledge, changes in stages of concern profiles, and acquisition of knowledge by the students of participants. A pretest-posttest design was used. The sample consisted of 20 teachers and 53 intact classes. No significant differences were found between active and passive experimental treatments on the teacher knowledge and student knowledge variables. The teacher passive group had a significant increase in knowledge. Significant changes occurred within and between experimental groups on the stages of concern variable.

The investigation of teacher change and student attitudes through the use of the Concerns Based Adoption Model was the subject of a study by **Merrick** (1987). This investigation utilized the Concerns Based Adoption Model to design and implement science in-service training for 31 K-9 teachers. Stages of Concern, Level of Use, and Innovation Configurations data were collected. These dimensions were placed on a best fit matrix to determine teacher needs. Matrix use identified training interventions matched to diagnosed needs. Six 2-1/2 hour training sessions were conducted over a seven week period. In addition, teachers completed 14 hours of personalized tasks related to their perceived needs and personal priorities. Science attitudes of the teachers' students were also obtained. Significant findings included pre- and post-training concerns differences, directional change in teachers' concerns, and increased use of innovation components during training.

Pendarvis (1987) studied the impact of integrated process skills training for teachers. The purpose of this study was to assess the impact of an in-service program, Teaching

Experimenting to Mississippi Teachers (TEMT), on integrated process skills and anxieties toward teaching science and teaching experimenting for junior high science teachers. Also, skill acquisition and attitudes of the students of these teachers were studied as a measure of teacher classroom performance. The teacher population consisted of 70 junior high science teachers from 9 districts. The treatment group, 40 teachers, underwent extensive integrated process skill training, whereas the control group of 30 teachers did not. A population of 344 students were in classes of teachers in the treatment group, while 202 students made up the control group. Based on the findings, the following conclusions were drawn. The TEMT program (1) significantly reduced anxieties of teachers regarding teaching science and experimenting; and (2) significantly improved the integrated process skills of teachers. Moreover, the unit emphasizing integrated process skills significantly improved acquisition of these skills by junior high students. Finally, this unit did not affect students' attitudes related to science.

The purpose of a study by **Salas** (1987) was to contribute ideas toward improving the effectiveness of chemistry teachers of Costa Rica. A review of teacher education literature was followed by the planning and implementation of an in-service workshop. A theoretical in-service model and syllabus resulted. This model was composed of five interdependent programs. No information as to the testing and/or validation of this model was made available.

While, Hendrix, and Mertens (1987) reported the findings of an in-service effort dealing with bio-social goals and human genetics. This research focused on selected teaching practices of biology and life science teachers who participated in one of a series of summer science workshops held in 1978, 1979, 1980, and 1981. The *ex post facto* design employed a study-specific questionnaire to examine content and methods used by the criterion group of NSF workshop participants and a control group. The criterion group consisted of 108 teachers from four contiguous states who had completed the workshop from 1978 to 1981. The control group consisted of 201 randomly selected teachers with similar backgrounds. Final results were based on data provided by 217 teachers after purging respondents with dissimilar teaching backgrounds. The subjects were 72.4% male and 27.6% female. Teachers in both groups indicated that they stressed the use of biological concepts to interpret human concerns. Teachers in the criterion group tended to delete non-human topics and incorporate more human topics. NSF participants also made significantly greater use of outside speakers. Finally, NSF participants appeared to rely on non-textbook material and techniques more than did their control group counterparts.

Evaluation of a teacher in-service training program in physical science was the topic of a study by **Lawrenz** (1987). The purpose of this endeavor was to describe and evaluate an in-service program for elementary/junior high teachers, thereby permitting future efforts to capitalize on its strengths and weaknesses. First, master teachers were identified. Next, these teachers attended a summer institute, and, finally, these trained teachers offered science in-service training in their local districts. Twenty (20) teachers were selected from a pool of 41 applicants. After one dropped out, 19 teachers, 11 men and 8 women, comprised the population. Three hundred and thirty (330) teachers enrolled in the local district classes. The summer institute teachers were pre- and posttested for science content, attitude toward science, and beliefs about science teaching. A random sample of 4th and 7th grade students of teachers in the fall classes was also pre- and posttested. In the summer institute, physical science was met with dissatisfaction. Pre- and posttesting indicated that participants gained in their beliefs about teaching science but dropped in terms of their attitude toward science. While conducting local classes, their attitudes were recharged to reflect positive feeling. In the local classes, the teachers viewed the program positively. Pre- and posttesting revealed positive effects. The teachers also improved in content knowledge.

Maoldomhnaigh (1987) examined the effects of a five day course on the teaching methods of Irish primary teachers. The course included hands on experiences, discussions, and work cards that listed the content and procedures the teachers explored during the workshop. Two cohort groups were compared. The first group (N=15) took the course in 1983 and reported a significantly greater number of hours devoted to experimental science in the classroom than the second group (N=16), which took the course in 1984. There was a significant increase in the number of hours that both cohorts spent on experimental science after the course. The author suggested that these increases pointed out the effect of the in-service courses.

2.82 What do teachers report as important needs for their professional growth?

Mullenex and Smith (1987) described an attempt by a university located in a rural area of Virginia to address the needs of surrounding school districts in science and mathematics. The Valley of Virginia Science and Mathematic Consortium (V SMC) was established at James Madison University on July 1, 1984 with funding from the State Council of Higher Education in Virginia. This project was a cooperative effort of the university's mathematics and science departments, some departments of the college of education and human services, and 22 school divisions in the Shenandoah Valley region. A needs assessment of the 22 school divisions identified general major needs, listed as follows in order of priority: (1) content courses for both elementary and secondary teachers in the content areas of science and mathematics; (2) curriculum development in science and mathematics; (3) science activities for primary and elementary grade students; (4) resource guides for teachers which describe available instructional television (ITV) programs, computer software, and human resources to complement the science and mathematics curricula; (5) conference for high school students at the University in the areas of science and mathematics; and (6) funds to purchase needed equipment and materials. Additional needs were identified by some school districts.

Al-Mossa (1987) conducted a needs assessment of Saudi intermediate school teachers of science. The purpose of the study was three-fold: (1) identification and adoption of a reliable and valid needs assessment; (2) use of the instrument to assess perceived needs of science teachers; and (3) use of the instrument to examine potential differences in these perceived needs regarding respondents' role variable and teachers' variables. The final Arabic version of the STIN Form B was validated and distributed to 192 science teachers, 40 principals, and 43 science supervisors. An interview was used as a supplemental instrument to elicit more information and to obtain more information as to the content validity of the main instrument. Using descriptive statistics, the top 25 needs were determined. Factor analysis techniques were used to make an accurate identification of factor needs and to support the construct validity. This analysis resulted in fifteen factor needs which were obtained from the six categories of the STIN-B, one factor at a time. One-way analysis of variance indicated that a significant relationship existed between the intensity of the professional needs of science teachers and the location of their school (rural and urban), nationality, their attendance at in-service programs, and their educational level.

In another international study, **Adi** (1987) looked at the perceived in-service training needs of science teachers in public secondary schools in Indonesia. This study gathered the perceptions of teachers, administrators, and teacher educators regarding the in-service needs of science teachers. Respondents included 133 senior secondary teachers, 19 teacher educators, and 23 administrators. Each rated the degree of needs of science teacher in-service competencies, as mandated by the Ministry of Education. Data were gathered through a questionnaire. Results indicated significant differences in perceived needs of nine competencies among teachers, administrators, and teacher educators; and eleven competencies among biology, physics, and chemistry teachers. While teachers and teacher-educators perceived 'mastery of subject area content' as most important, administrators perceived 'use and management of lab teaching for teaching-learning process' as the most important.

Responses of American pre-service teachers on Kimball's Nature of Science Survey were used as a basis for comparing their Nigerian counterparts by Cobern (1987). It was apparent that the Nigerian students were more inclined to see science as a way of producing useful technology than were the American students. The second distinction indicated that Nigerian students perceived scientists as more nationalistic and secretive about their work.

Actual teaching experience is often an important criterion in assessing differences between the pre-service and in-service teacher. Several problems and concerns persist, however, for both teacher groups related to science teaching, as indicated by this review. The most prevalent similarities, initially reported for pre-service science teacher education and continuing among in-service science teachers were: (1) anxiety regarding the teaching of science content, processes, and specifically science experimentation; (2) a generally passive attitude toward science and science teaching; and (3) a lack of adequate understanding of nature of science. Concerns 1 and 2 were far more common among elementary science teachers, and the third concern continues to be a problem at all levels of science teaching.

In-service science teachers, in addition, voiced a strong preference for district-identified in-service workshops rather than outside sponsored workshops. If in-service teachers are expected to implement innovations or new programs, then partnerships between districts and the outside delivery agencies need to be established and maintained with a greater degree of input from the users of such innovations and new programs, the in-service teachers themselves.

Finally, we note with interest that one common reaction to persistent problems among in-service teachers is to blame pre-service teacher education programs. Several studies in this review alluded to the need to improve pre-service science teacher education programs, in hopes that many of the on-going, persistent problems cited above could be addressed and remedied. While continued research for the purpose of improving our understanding and design of pre-service science teacher education programs is extremely important, we should not necessarily expect such improvements to either remedy the above mentioned problems or remove our obligation to consider the lifelong learning needs of the teachers we produce. As pre-service teachers graduate from our programs, however improved such programs might become in the future, we need to continue to solicit, assess, and respond to the self-perceived needs of our science teacher education program graduates.

3.0 CURRICULUM AND INSTRUCTION

Whereas learners and learning are the central focus and whereas teachers shoulder the responsibility for learners and learning, curriculum and instruction represent vehicles for achieving learning goals. Linn (1987) argues that the goals of the science curriculum need redefinition and expansion to reflect new knowledge, technological advances, and societal needs. Curriculum development and instructional design should include factors that motivate students, depth at the expense of breadth, integrated rather than partitioned knowledge, and instruction and feedback through new technologies. Moreover, new tests are needed which assess the types of complex learning reflected in a new science curriculum.

We examined the literature in 1987 keeping in mind Linn's arguments. Within the third commonplace, we have segmented the reports into six areas, the impact of technology, the emphasis on problem solving and inquiry, the use of language arts and organizational devices, implementation of methods, aspects of the curriculum itself, and the development and validation of instruments. We begin with a focus on technology.

3.1 The Impact of Technology

Earlier we noted Linn's (1987) observations and descriptions of emerging research themes in science education. Another theme described by Linn (1987) is the utilization of new technologies. For example, computer technologies not only let students accomplish old tasks in new ways, but permit them to tackle tasks that were heretofore impossible. Moreover, researchers are using new technologies to study numerous aspects of curriculum and instruction. The studies reviewed in the initial section share the common thread of new technologies applied to research on curriculum and instruction.

3.11 What problems must be solved to realize the potential of intelligent computer-assisted instruction?

In a theoretical paper, Good (1987) examined the concept of artificial intelligence as it relates to intelligent computer-assisted instruction and science education. He maintained that the important parts of intelligent computer-assisted instruction were modeling the student, teacher, and the natural environment. To realize the potential of intelligent computer-assisted instruction, he stated that researchers must solve three problems: (1) the soft knowledge base of teaching and learning; (2) natural language processing; and (3) machine learning. Moreover, science educators must learn to make accurate diagnoses of students' learning states just as physicians do of patients' health. Good concluded by describing a revision of the well known SCIS learning cycle based on cognitive science and artificial intelligence principles. The revisions included the addition of the concept 'prediction' to exploration, concept invention, and concept application as well as the transformation of the learning cycle as a linear model into a more flexible model through prediction.

3.12 How will computer technology modify curriculum and instruction?

Tinker (1987) speculated that the maturation of computer hardware and software technology would open new possibilities for broad-scale, technologically enhanced changes in the mathematics and science curriculum. He suggested that this would not happen through small application-specific packages, but through powerful, general software tools in the same class as those revolutionizing business. Except for the 'productivity tools' imported from business, a sufficiently powerful integrated set of software tools does not exist for mathematics and science education. Tinker argued that new opportunities created by emerging technology could make a major contribution to improving the understanding of mathematics and science by all students. Capitalizing on these opportunities will require major changes in the curriculum and teaching methods, changes which, given the slow pace of educational reform, may well take decades. However, the beginning steps are clear: (1) train teachers to enable them to take advantage of the new opportunities; (2) develop software and course materials that begin to move in this direction; and (3) initiate large-scale curriculum experimentation in schools to model new directions that must be taken.

diSessa (1987) published an article titled "The Third Revolution in Computers and Education." He considered the first revolution to have begun with the realization that computers could revolutionize the way we think about thinking and deal with learning. The second revolution was the current decrease in prices that has made computers available in school settings. The third, he argued, is just beginning and will allow us to use computers to better understand the fundamentals of knowledge and learning and "turn the art of education into a principled scientific and engineering enterprise with leverage in terms of educational achievement far beyond what we historically expect of an evolving but largely informal and inarticulate profession" (p. 364).

3.13 How is computer technology being used to enhance student achievement?

Using the Extended Microcomputer-Based Laboratory (MBL) motion graphing experience, **Brasell** (1987) studied the ability of students to translate between a physical event and its graphic representation as well as the effect of real-time versus delayed graphing of data. Ninety-three (93) physics students throughout seven north Florida rural schools participated in the one-day experiment. The four levels of instruction were MBL real-time, MBL 20 second delay, a control group that performed paper-and-pencil activities which paralleled the MBL instruction, and a test-only control group. Results showed that students in the MBL real-time group outperformed all other groups on post-test achievement, primarily on the distance sub-test. A reduction in graph errors was primarily responsible for the difference, and the real-time graphing feature was attributed as a principal source.

In another segment of the study, **Brasell** (1987) examined the differences between males and females with respect to their performance on computer graphing tasks and their attitudes toward graphs and graph-based activities. Pretesting of 93 students revealed that about one-fifth possessed an inadequate graph scheme. Females with inadequate graph schemata seemed constrained by low ability, whereas males were constrained by lack of interest. Females had lower pre-test scores for speed and velocity graphing items but did as well as males on distance graphs. Using a microcomputer-based laboratory (MBL) activity, 18 students constructed distance and velocity graphs for one class period, while 18 counterparts constructed the same graphs using paper and pencils. Females in the MBL group scored significantly better on post-test items about distance graphs than did males. The reverse was true for the velocity items. No gender differences were found in the paper-and-pencil group.

Nachmias and Linn (1987) examined evaluations by students of computer-presented information on temperature, heat, and energy concepts in the science laboratory. Two hundred forty-nine (249) eighth graders participated in 54 activities over an 18 week period in two phases using the Computer as Lab Partner Curriculum. In phase one Nachmias and Linn found significant decreases in the willingness of students to accept inappropriate graph scaling, probe setup, and probe calibration, but not probe sensitivity. After enhanced instruction in phase two, which emphasized graph scaling, experimental variation, probe calibration, and graph validity, students in phase two increased their performance on graph scaling and experimental variation, showed no significant difference in probe setup and calibration, and decreased in probe sensitivity relative to their counterparts in phase 1.

Berger, Pintrich, and Stemmer (1987) examined the performance of students on linear and logarithmic estimation tasks using a microcomputer. Forty (40) seventh and eighth graders participated in the study. Results showed that linear estimation by students could be described by a general learning curve with performance improving over time. Logarithmic scale estimations of students, however, could be described by a complex interaction involving the number of estimations trials with the position of the estimation target on the logarithmic scale. Usage of various strategies did not influence linear task performance, but did influence logarithmic task performance. Specifically, students who utilized the midpoint of the scale as a marker did better in terms of their average number of estimates than their counterparts who utilized elimination, counting, or guessing.

Linn, Sloane, and Clancy (1987) studied 14 high school AP Pascal programming classes to see how programming skill was related to instruction. High, medium, and low proficiency classrooms were found to differ in instructional characteristics as well. Classes showing the greatest skill also had more computer access time, more individual attention from the teacher (rather than lecture), greater encouragement to explicitly plan their programs before coding, and more prompt feedback.

Pintrich, Berger, and Stemmer (1987) studied Pascal coding and debugging programming skills. They found that high school students in general did not plan ahead, but started immediately to code their programs, and that they debugged largely through trial and error.

Rivers and Vockell (1987) examined the problem solving performance of high school biology students with computer simulations in unguided discovery, guided discovery, and control conditions in three separate studies. For three of the simulations (OSMO, MONOCROSS, MOTHS), there was no significant difference in gain rate on problem solving with respect to the specific subject matter. For the PLANT and BALANCE simulations, students in the guided discovery group outperformed the other groups, and students in the unguided discovery group outperformed those in the control group. On general problem solving, students in the guided discovery group outperformed the other groups.

Mokros and Tinker (1987) reported the results of two preliminary studies and a longitudinal study using the Microcomputer-Based Laboratory (MBL) curriculum. The first preliminary study found graph-as-picture errors and slope/height confusions among students, but Mokros and Tinker questioned their status as misconceptions due to the ease of removal of these difficulties via MBL. In a three-month longitudinal study using MBL, students demonstrated significant gains on 16 graphing items, although the instruction focused on science topics rather than graphing skills. The researchers identified MBL features of multiple modality, real-time pairing of events with their graphic representations, use of genuine scientific experiences, and elimination of drudgery in producing graphs as contributors to its success in improving graphical communication.

Hess (1987) reported an experimental test of the professionally programmed instruction called Watts. Using 223 sixth through ninth graders, heterogeneously grouped in a pre-test-post-test design, Hess found significant achievement gains and a grade level effect, but no effect due to gender and no interaction of grade with gender. Students and teachers reacted positively to the computer simulation in terms of its organization, ease of use, effectiveness, and applicability to the curriculum.

A number of research studies were conducted that compared various instructional strategies using either computer instruction or the conventional mode of instruction. **Rowland and Stuessy** (1987) assessed the effects of two modes of computer-assisted instruction, simulation and tutorial, on the ability of pre-service elementary teachers to understand relationships between a number of concepts dealing with home energy. Instruments measuring various dimensions of learning style differences were administered to ascertain which learning style constructs interacted with mode of instruction to predict conceptual understanding and scores on an achievement test. Results indicated that achievement scores were higher for users of the tutorial; however, the number of valid concept relationships did not differ by treatment. In addition, a difference in achievement scores favoring the tutorial was found in subjects exhibiting an external locus of control, field independence, and/or high discrimination skill. Other individuals showed no difference in achievement by treatment. Finally, subjects whose holist/serialist orientation was matched to the appropriate mode of instruction scored higher on the achievement test than did those who were mismatched.

Dixon (1987) reported an experiment in which the efficacy of a computer-based model using expert and novice modes for teaching decision making in the National Park Service domain was compared to a traditional method which included lectures, field trips, and demonstrations for a sample of Natural Resources Management candidates from the National Park Services. A pre-test-post-test-control group design was used. Results suggested that a computer based decision-making process could be employed to enhance the decision making performance of students beyond that of the traditional instruction.

Eisenkraft (1987) compared the use of computer simulated experiments to traditional laboratory work on the comprehension of physics students. Two hundred twenty-five (225) physics then randomly assigned as individuals to perform a pendulum lab and a lens lab via computer simulation or via traditional laboratory work. Results showed that students with higher mechanical comprehension recorded more data points, discerned the functional relation better, and scored higher on the post-test than did students with lower mechanical comprehension. Moreover, students in the computer simulation group recorded more data points, discerned the functional relation better, and scored higher on the post-test than did students in the control group. Eisenkraft also found significant two-way interactions, in that students in the computer simulation were equally successful regardless of their mechanical comprehension, whereas students in the technical lab were more successful if they possessed higher mechanical comprehension. Also, achievement test scores were higher for students with high mechanical comprehension in the traditional group but were lower if they were in the computer simulation group.

Choi and Gennaro (1987) studied the acquisition of volume displacement by junior high school students. The experimental method, microcomputer simulations of experiences, was contrasted with the control, hands-on instruction. Using a post-test-only control group design, Choi and Gennaro randomly assigned boys and girls to the experimental or control group. Results showed that computer simulated experiences were as effective as hands on experiences, that boys in the control group outperformed girls in the control group on the post-test, but that boys and girls in the experimental group performed equally well. A retention test again showed no significant performance differences between the experimental and control groups, but the males in both groups retained more than the females on the retention test.

A number of computer studies involved the chemistry laboratory. **Bourque and Carlson** (1987) examined and compared the cognitive effectiveness of a traditional hands-on laboratory exercise with a computer-simulated program on the same topic. In addition, they attempted to determine if coupling these formats would provide optimum student comprehension. The authors concluded in the first phase of the study that the hands-on experimental exercise produced significantly higher learning scores in the acid-base titration experiment and the ionization constant experiment, but no difference for the determination Avogadro's number experiment. The results were explained as follows: (1) the hands-on activities provided students a more realistic understanding of the trial and error process by involvement with careful observations and manual skills required for gathering accurate data. Also, the hands-on labs seemed to emphasize the mental activity to assimilate the abstract concepts involved in the complex chemical interactions under study; (2) in the lab activities, the post-lab write-up required a response to a series of related questions and problems dependent on the subjects' understanding of the experimental concepts and problem-solving skills; (3) the simulation programs were not provided with an equivalent tutorial set of questions or a conclusive problem-solving activity; (4) within the computer format all calculations were computer programmed and the students did not put forth as intense an effort to derive or discover the mathematical computations. The problem exercises had a direct relationship with the improvement in cognitive scores; and (5) there was no difference in the Avogadro's number experiment because in either instructional procedure, the format was so structured that the students followed computation in dimensional analysis without fully understanding what was happening. Results of the second phase of the study indicated that the hands-on experiment followed by the computer-simulation format provided the highest cumulative scores for experiments on the acid-base titration and the equilibrium constant of a weak acid. There was no apparent advantage in the performance sequence for the Avogadro's number experiment. The authors reported that the students preferred the hands-on experiments before attempting the computer simulation and listed the following reasons: (1) students liked seeing the reagents and actually viewing the reaction changes; (2) they became familiar with the manipulation of the laboratory equipment; and (3) they actually saw what was happening by doing it first and thus gained a greater appreciation for the simulation program which was used to confirm and reinforce their newly acquired knowledge. **Jackman, Moellenberg, and Brabson** (1987) designed a study to determine the relative effectiveness of different instructional approaches on chemistry laboratory achievement through investigating differences in achievement in spectrophotometry among college freshmen who received either traditional, learning cycle, or computer simulation instruction. Approximately 300 second-semester general chemistry laboratory college students participated in the study, with random assignment by sections to one of the three treatment groups. Subjects worked in pairs in all instructional methods. The traditional and learning cycle methods, but not the simulation, contained a pre-laboratory exercise that was given to students one week prior to the remainder of the laboratory exercise. All subjects were administered a pre-test and post-test of spectrophotometry achievement. Analysis of covariance indicated a significant difference among the three instructional methods, and the adjusted post-test mean for subjects taught by the simulation was significantly greater than the adjusted mean for students taught by the traditional method or by the learning cycle method. There was no difference in the means of the subjects taught by the traditional and learning cycle methods.

Stevens, Zech, and Katkanant (1987) evaluated the effectiveness of implementing an interactive videodisc science lesson on titration into a high school science program. Results were measured on achievement and attitude instruments along with observational data. The basic conclusion of the study was that no significant differences existed in achievement or attitude between the students who received the interactive videodisc (IVD) lesson on titration first and students who received the laboratory experience first. In other words, as far as achievement and attitudes were concerned, it did not make any difference whether students used the IVD lesson before or after conducting the experiment or reversed the process. The researchers concluded that this finding was important to classroom teachers who try to manage two modes of lab instruction with limited equipment and lab stations. The observational data, however, showed that time, types of errors, and accuracy were influenced by the order of the events. Students who completed the titration process using the IVD first spent much less time setting up equipment and conducting the experiment than students who began their experiences in the lab.

Olsen (1987) studied the effects of various presentations of objectives on learning a set of four acid-base chemistry lessons presented on a microcomputer interactive videodisc (MCIV) system. Focusing on the possibilities of how objectives could be presented to the learner, the author analyzed and compared the achievement of high school chemistry students receiving MCIV instruction. Students were randomly assigned to one of three groups: (1) those presented with lesson objectives, identified as objectives, through text; (2) those presented with objectives through text and visualization; or (3) those who heard only the goals, stated on audio track, but no objectives. Results indicated no differences among the groups on the learning of verbal information and intellectual skills, and the amount of time students spent on the instructional materials. Also, there was no correlation between time and post-test scores. Chi-square analyses indicated no significant differences among treatment groups on their responses to attitudinal scores. However, the majority of students were very positive about their experiences with the MCIV lessons. The researcher suggested that the finding of non-significance might be attributed to the effects of instructional novelty, or to the structured materials being used.

Oringer (1987) evaluated Planning for Power, a computer simulation which allows a team of up to three middle school students the opportunity to deal with issues relating to locating new electrical power plants in two large communities. The program included a physical mode, printed instructional materials for students, and lesson plans for teachers. The subjects, from suburban New York City, were evaluated on a standardized test, an achievement test, a student questionnaire, and a teacher questionnaire. The achievement test was administered prior to and at the end of the instructional period. The post-test mean was about two-fifths of a standard deviation above the pre-test mean, and both eighth and ninth graders had a significantly higher gain than did seventh graders. Moreover, there was an effect due to gender with boys at a higher level than girls.

Data revealed a gain of one-half of a standard deviation. A step-wise regression analysis revealed that the predictors accounted for 61.5% of the variance in post-test scores. Students reacted positively to the experiences, including the organization and quality of the instruction. Teacher reactions were also favorable but less positive than those of students.

El-Assad (1987) surveyed teachers in Los Angeles County to determine the extent of computer use in teaching biological sciences at selected public high schools, to investigate the effects and changes, if any, that have taken place in the related curricula as a result of using computer technology instruction, and to analyze the attitudes of teachers towards the integration of this use. There were three major findings as follows: (1) the biological sciences curriculum had remained constant or changed very little as a result of using computers; (2) most teachers rejected the need for a redefinition of the major goals of science in the school program; and (3) most biology educators believed that computers could not replace the teacher or the textbook in the classroom.

Collins (1987) described the problem-solving strategies of experts solving realistic, computer-generated transmission genetics problems and set forth implications for instruction. Seven experts were involved in the study. Each had a doctoral degree and experience in teaching and research in genetics. Two types of data were available for analysis and for the description of the strategic knowledge that was used by the experts. These were the transcripts of the think aloud protocols and the computer printouts of the sequence of crosses for each genetics problem. Based on the analysis of the results, it was determined that experts solved introductory level realistic transmission genetics problems by employing a strategy of data redescription (identifying traits, variations and classes of phenotypes, and their distribution) prior to the formulation of tentative general hypotheses. The next step, called hypothesis, was the strategy of solution synthesis. Hypothesis testing the classes of problems considered in the study required a definitive cross usually using zygotes. The third step was the strategy of solution assessment which consisted of producing additional evidence to confirm the inferred hypothesis. Experts in genetics knew when and how to use the strategies to successfully solve realistic problems. The solution was the identification, by inference from the problem data generated, of general hypotheses about inheritance patterns and modifiers. The experts, having tested and confirmed the hypotheses by using them to explain and predict data, had a high degree of confidence that was justifiable from the data.

Fletcher and Collins (1987) designed a study to determine whether or not biology students were being disadvantaged by taking computer tests instead of paper forms of the same tests.

Results indicated that mean scores on computer-administered and written forms of the same test were approximately equivalent.

Heath, White, Berlin, and Park (1987) studied the number of alternatives generated by 2nd and 4th grade students in interview versus computer simulation of decision-making. They found that children generated a greater number of alternatives in the interview than in the simulation setting.

Two studies dealt with the use of microcomputers in the remediation of scientific misconceptions. **Murray, Schultz, Brown, and Clement** (1987) developed a computer tutor designed to help students gain a qualitative understanding of important physics concepts. The tutor simulated a teaching strategy called 'bridging' analogies that previous research had demonstrated to be successful in one-on-one tutoring and written explanation studies. The strategy was designed to remedy misconceptions by appealing to existing correct intuitions, and extending these intuitions by encouraging analogical situation. Analysis of these data indicated those situations in which the strategy worked well and those where alternatives were needed. Implications incorporated a representation of student beliefs and intelligent sequencing of example presentations.

Reif (1987) explored the use of instructional design, an understanding of cognitive processes, and computer technology in the teaching of concepts in physics. Students were taught an explicit procedure specifying the concept 'acceleration' and then diagnosed and corrected mistakes committed by themselves or others. Such teaching greatly improved concept interpretations of students and blocked previous misconceptions. The researcher concluded that computers could provide powerful tools for research on instructional design and for implementing more effective teaching.

3.14 What are the characteristics of exemplary computer software?

Krajcik, Berg, and Cathcart (1987) reported on the characteristics of exemplary science software. In sum, exemplary science software (1) actively engaged students in the learning process; (2) enhanced and complemented traditional teaching instruction; (3) contained dynamic visuals to represent abstract concepts; (4) allowed for exploration not normally allowed in the science classroom due to constraints of time, danger, or money; (5) permitted the collection, graphing, interpretation and analysis of data; (6) provided opportunities to plan, synthesize, question, predict, and apply; (7) helped students develop higher order thinking skills; (8) contained several levels of difficulty that could change to meet the needs of the student; (9) provided meaningful, informative, and corrective feedback; (10) made use of excellent technical features including uncluttered screen design, lean text, help screens, and self-pacing; and (11) contained clearly stated objectives. Examples of software programs that exhibited such features included Baffles (Conduit), Geology Search (McGraw-Hill), Birdbreed (EduTech), Discovery Lab (Minnesota Educational Computing Consortium), Models of Electric Current, Ohm's Law (Conduit), Standing Waves (Conduit), CATLAB (Conduit), and Factory (Sunburst).

Clearly, computer technology is a powerful tool to study problems in teaching and learning. As new developments in computer software become available through the invention of powerful, generic software packages, opportunities will exist for large-scale curriculum experimentation and scientific exploration of teaching and learning. During 1987, a variety of research studies evaluated the impact of computers on student achievement. In most cases, the use of computer technology had a positive impact on learning. In four studies, researchers found that graphing skills and linear and logarithmic estimation skills of students were improved when compared with paper and pencil instruction. One study discovered differentiated responses between males and females performing significantly better on distance graphing and the reverse on velocity.

Most of the remaining computer-based instruction studies dealt with the impact of computer technology on problem solving/decision making and the acquisition of science concepts and principles. When compared to conventional instruction, computer simulated guided-discovery and decision making activities tended to produce superior results. In comparing hands-on laboratory experiences to computer simulated experiences, the computer instructed students either did as well or were superior in performance. Abstractness of the tasks, complexity of the data sources, age, gender, and student aptitudes contributed to various interactions that led to mixed results. In most cases, students liked their instruction with computers and found their use to be beneficial, even when there were no data to support the conclusion.

It is clear that computers have a positive impact on instruction in many cases and little negative impact. In most situations computer-based instruction is time and cost effective compared to conventional instruction. The interaction of specific instructional tasks and student aptitudes appears to be a very productive line of research that needs to be emphasized in the future.

3.2 Problem Solving and Inquiry

3.21 What is the impact of inquiry and other problem-solving instructional strategies on science learning?

Faraj (1987) investigated whether using the inquiry method in teaching science in the State of Kuwait elementary schools was better than using the existing traditional method. The researcher worked with four teachers in two different schools, with two classes taught by two teachers using the inquiry method. The other two classes were taught by the remaining two teachers using the traditional method. During the teaching of a 13 lesson unit about magnets, with each lesson having a duration of 45 minutes, the researcher observed the students in order to record the number of times the students were involved in each of five inquiry science experiences: (1) observation; (2) measurement; (3) experimentation; (4) interpretation of data; and (5) prediction. On completion of the unit the researcher gave a uniform exam to all students. Analysis revealed a significant difference in favor of the group that learned by the inquiry method in the number of times the students were involved in each of the five essential science experiences. When compared on the final test, the inquiry group students scored significantly higher than the group that learned by the more traditional method.

Wirt (1987) investigated the relative effectiveness of a laboratory oriented, inquiry based chemistry course that included additional training in logical thinking skills versus the traditional lecture chemistry course. Both groups were pre-tested and post-tested using the Cooperative Science Test, Chemistry, Form A, for achievement and the English version of the Longeot test for cognitive intelligence. The same textbook and the same subject matter were covered in all classes. Chi-square analysis showed significant differences in the predicted direction for the use of inquiry in the activities of the teacher and students, and in the teacher's position in the classroom. Analysis of pre-test scores indicated no significant differences between groups on chemistry achievement or cognitive intelligence. Post-test scores revealed a favorable difference on achievement for the inquiry group with no difference between the groups on cognitive intelligence. Also, multiple regression analysis indicated that formal operational students consistently outperformed concrete operational students, who performed the same regardless of the teaching method. Thus, there was no interaction between level of cognitive development and teaching method.

Denson (1987) examined the relationships between field independent or field dependent cognitive styles, general chemistry knowledge, and process skills of students taught by either an investigative or a conventional laboratory method of instruction. Intact laboratory sections were randomly assigned to either the experimental or control group. The American Chemical Society Examination and the Test of Integrated Process Skills were utilized to obtain pre- and post-scores. The Group Embedded Figures Test was used to classify the field independent or field dependent cognitive style of the students. Significant relationships were found between cognitive styles and process skill development of chemistry students taught by either an investigative or a conventional laboratory method of instruction. The relationship between cognitive style and knowledge of chemistry was not significant for either laboratory instructional method. Data analysis showed that the investigative and conventional laboratory methods did not produce significant differences in the knowledge of chemistry or process skill development of students for either field-independent of field-dependent cognitive style. Neither the investigative nor the conventional instructional method was superior to the other in terms of improving knowledge of chemistry and process skill development of students with various cognitive styles.

Mulopo and Fowler (1987) examined the differential effectiveness of traditional and discovery methods of chemistry instruction in Zambia. Compared were the teaching of science concepts, understandings about science, and scientific attitudes of learners at the concrete and formal levels of cognitive development. The dependent variables were achievement, understanding science, and scientific attitude. Variables were assessed through the use of the ACS Achievement Test (high school chemistry, Form 1979), the Test on Understanding Science (Form W), and Test on Scientific Attitude, respectively. Mode of instruction and cognitive development were the independent variables. Subjects were 120 11th grade males enrolled in chemistry classes in Zambia. Sixty (60) of the subjects were concrete reasoners randomly selected from one of the two schools. The remaining 60 subjects were formal reasoners randomly selected from the second school. Each of these groups was randomly split into two subgroups with traditional and discovery approaches of instruction randomly assigned to the two subgroups of concrete reasoners and the two subgroups of formal reasoners. Subjects received instructions covering eight chemistry topics during approximately 10 weeks. Analysis of the data revealed that: (1) for the formal reasoners, the discovery group scored significantly higher on understanding science than the traditional group. For the concrete reasoners, mode of instruction did not make a difference; (2) overall, formal reasoners earned significantly higher achievement scores than concrete reasoners; (3) in general, subjects taught by the discovery approach scored significantly higher on scientific attitude than those taught by the traditional approach; and (4) the traditional group outperformed the discovery group in achievement. It was concluded that the traditional approach might be an efficient instructional mode for the teaching of scientific facts and principles to high school students, while the discovery approach seemed to be more suitable for teaching scientific attitudes and for promoting understanding about science and scientists among formal operational learners.

Jordan (1987), using information processing as a theoretical base, sought to determine whether or not specific cognitive strategies could be taught and learned. These strategies dealt with memory skills which had been shown to occur naturally in mature learners. However, it had also been shown that even some university students lacked these basic skills and resorted to ineffective memory techniques. This resulted in failure to recall information and an inability to resolve problem solving tasks. Four tasks were designed as follows: (1) summarizing a reading; (2) self-testing vocabulary; (3) writing questions; and (4) writing answers. Grade nine science students were assigned to an experimental and a comparison group. Both groups were asked to follow an outline based on the Canadian British Columbia Provincial Curriculum for grade 9 science. One group was assigned predetermined tasks from the text while the experimental group utilized the designed tasks. In the analysis, the recall and problem solving segments of the post-test comprised the variables of the dependent variable set while the pre-test scores in grade 8 science and the Arlin Test of Formal Reasoning constituted the measures on the variables for the independent variable set. An initial canonical analysis determined the relationship between the two sets of variables. An analysis of covariance was performed using previous achievement and the pre-test. A post-hoc Scheffe Test analyzed contrasts between groups regarding development level. The results showed statistically significant differences in favor of the comparison group on recall and the experimental group on problem solving. No interactions were found between the variables and the grouping. Further analysis indicated that while the results were statistically significant, mean score differences were very small. The observation was made that while results might be statistically significant, they also might be educationally questionable. The researcher argued that the unit taught was incorrectly assumed by teachers, curriculum developers, and the researcher to be new material. It was further suggested that this information had become common knowledge. Although the teachers found the materials useful, prior knowledge of the subjects prevented clear answers to the research questions asked.

Young (1987) evaluated the effectiveness of an instructional model derived from the research on learning styles, science curriculum development, and the development of thinking skills. The model implied that a specific sequence of instructional strategies which included a discrepant event, discussion, experimentation, practice, and application would result in significantly higher achievement among students of all learning style preferences compared to traditional science instruction relying primarily on textbook and lecture. Seventh grade students were randomly assigned to one of two treatments for a total of 24 weeks. Dependent variables included student mastery of science concepts as measured by the Stanford Achievement Test, basic skills as measured by the Comprehensive Test of Basic Skills Science Test (CTBS-Science), and creative thinking as measured by the Torrance Test of Creative Thinking (TTCT). Multivariate analyses of covariance were used to examine the dependent variables with treatment, student learning style preference, and gender as independent variables, and CTBS pre-test as a covariate. No significant interactions were found. Main effects of learning style and gender were not statistically significant. The main effect of treatment was statistically significant, affecting a linear combination of dependent variables composed of CTBS, 'Verbal Originality', and 'Figural Elaboration'. The researcher concluded that using a variety of instructional strategies in a preplanned sequence in science significantly affected student achievement of basic thinking skills, verbal creative thinking, and figural creative thinking, while not jeopardizing mastery of science concepts, regardless of gender, for students of all learning-style preferences.

Brown and Clement (1987) studied the effectiveness of an analogical teaching technique, which used a connected sequence of 'bridging' analogies, compared with a more standard teaching-by-example technique. The target concept involved the common misconception that static objects are unable to exert forces. Of the 21 high school students with no prior physics instruction who were individually interviewed, 14 initially maintained that a table does not exert a force upward on a book resting on it. The latter were divided into two matched groups. Students in each group were asked to think aloud as they worked through one of the two written explanations. After instruction, the experimental group performed significantly better on target and transfer problems, as well as indicating significantly higher subjective estimates of how 'understandable and believable' the explanation was. The authors drew upon the findings for the following suggestions: (1) teachers should be aware that certain examples which they find compelling might not be at all illuminating for the student; (2) if the examples are compelling to the student, it still might not be seen as analogous to the target problem in the lesson; and (3) teachers should keep in mind the goal of helping students develop visual, qualitative models of physical phenomena.

Ross and Robinson (1987) investigated the effects of various strategies on how to use rules in teaching experimental design in science classes. The experimental treatments included the use of three sets of instructional materials for teaching experimental design. The materials were prescriptive in nature and were designed as five 40-minutes lessons. One set of materials incorporated implicit rules, a method in which the rules were not made visible to students, although the instruction of teachers with students was guided by a checklist that outlined the steps of the procedure. A second set of materials used the teacher-enunciated rules procedure in which the student was given the rule structure at the outset of instruction. The third set of materials used the student-retrieved rules in which the students, as a large group, developed a set of rules for designing experiments. Two open-ended tests of experimental frame-working were developed by the researchers. Each was a test of near transfer in that the content of the item was unrelated to the content of the science unit. Post-test scores were significantly higher than pre-test scores in all three treatments. When the pre-test scores were controlled for the full sample via analysis of covariance, the results showed no significant differences in the effects of treatments on simple experiment indicators. However, significant differences were found in the effects of treatments on controlled experiment indicators such that students in implicit-rules and teacher-rules treatments outperformed students in student-rules treatment. In both cases, there was no significant interaction of gender and treatment. The author concluded that varying the treatment of rules in alternate instructional strategies had little differentiating effect on learning the skill of experimental design. The one exception involved relatively lower performance on one set of indicators in the student-rules treatment. The authors proposed the following reasons to explain the essentially same effects of different treatments despite their different theoretical prognostications: (1) there was an unconscious blurring by the investigators of the theoretical advantages of different treatments in the operational forms that were tested; (2) the factor that might have been observed was the difference between student and teacher rule treatment and in both cases the rules appeared clearly in the total sequence of instructional activity; (3) teachers unconsciously varied 'script' and 'using strategies' from the other treatments.

In another article that addressed the use of experimental design in science instruction, **Lucas and Tobin** (1987) described situations in which multiple variables could be used in student experiments. The authors argued that control of a single variable was an inadequate conception of experimentation. Further, they believed that students who learn multiple variable methods would go on to explore the concept by experimental methods at higher conceptual levels.

Ost (1987) discussed the model as a tool and modeling as a process in teaching science and mathematics. He suggested that there were four basic kinds of models found in contemporary science which have direct applications in teaching science and mathematics: (1) representative; (2) analogue; (3) logical; and

(4) theoretical. Moreover, he pointed out that models were not new to the classroom. For example, the physical sciences have long used analogue and theoretical models to explain principles and concepts. But even in these sciences the full potential of models has not been developed in the classroom. Ost concluded by stating that the future citizen, whether scientist or not, should understand the strengths and mechanisms of models as well as their limitations and pitfalls.

Stedman (1987) summarized historical records of inquiry teaching in science during the 1800s. He reported that American science probably began after the conclusion of the War of 1812, and college level science training began soon thereafter. He cited specific examples of student field trips in science as early as 1826. The report also included anecdotal information concerning the attempts of prominent American scientists to affect science education at the college level and mentioned historical landmarks such as the recommendation of increased lab work for secondary school science students in 1892 by the National Education Association (NEA). The author concluded that science teaching, in comparison to science, is relatively young in development.

Over the past ten to fifteen years, numerous studies demonstrated the superiority of inquiry and problem-solving hands-on science instruction compared to the traditional methods for a number of important educational outcomes. The 1987 review supports the earlier work. The studies reviewed indicated that the use of various problem solving instructional strategies by students improved their skills to solve similar problems in near transfer situations and improved creative thinking. Studies that explored specific cognitive strategies dealing with memory skills, 'bridging' analogies, teaching experimental design rules, and an instructional model based on learning styles and thinking skills research, all had a positive effect on problem solving skills and/or creative thinking without jeopardizing the mastery of science concepts. Several studies examined specific student aptitudes, with varying results. For example, the results of two studies, one at the elementary and the other college level, suggested that formal operational students achieved best with the discovery method while no difference was detectable with concrete students. Also, the formal operational students perform best overall regardless of the treatment. Other variables identified in the studies that merit future investigation included the impact of prior knowledge, learning styles, and gender.

3.3 Language Arts and Organizational Devices in Science

3.31 What are the effects of various reading and writing instructional techniques on science concept attainment?

Sharp (1987), investigated whether or not a particular type of expressive writing, expressive or freeform summary, would help students learn content information in a biology course. The researcher categorized learning into long-term and short-term learning and categorized learners according to two separate bases, treatment group, and level of academic preparedness: low, middle, and high. Long-term learning was the major emphasis of the study since the researcher expected to find positive results in this area. Subjects were students in three biology courses representing three ability levels. Students were given a pre-test and two post-tests to evaluate learning. The first post-test was given immediately following the instructed unit; the second post-test was administered three and a half weeks later without a review session. In addition, all students answered a questionnaire about their academic history and study habits. The experimental group wrote from one to three practice summaries and then wrote three summaries on cell structure. The control group students took notes in their usual way and allowed the researcher to view the notes. Statistical analysis of the data indicated that expressive summary writing seemed to help students learn biology better initially and to sustain this learning advantage over students who did not summarize expressively. Further research should be done with a larger sample of students at each of the three academic levels before drawing conclusions about the expressive summary writing on these students. The questionnaire results showed that expressive summary writing seemed to cause most students to have positive feelings about the helpfulness of the assignment.

Pace (1987) looked at the effectiveness of imagery as a technique for greater retention of science vocabulary terms. Subjects were fifth-grade students from 15 intact classrooms in a western North Carolina school system. They were randomly assigned to control, traditional science textbook, and imagery treatment groups. Data were collected over a period of five consecutive days during which the textbook and imagery groups received a total of 150 minutes of instruction under the guidance of the classroom teacher. The control group received the list of science vocabulary terms with no instruction. All groups received pre-testing, post-testing, and delayed testing four weeks following the last day of instruction. Results showed no significant difference between methods in regard to retention of vocabulary terms.

Leonard (1987) evaluated the relative effects of the presentation style of questions inserted into text materials for students in university introductory biology. Subjects were randomly assigned to seven treatment groups of approximately equal size and read a 2,354 word passage on bacterial adaptations taken from a popular university general biology textbook. Experimental treatment groups read the same passage with: (1) questions placed at the beginning of selected paragraphs. These questions were also presented as follows: (2) underlined; (3) in uppercase; (4) set above the paragraph; (5) underlined and set above; and (6) set above in uppercase, respectively. The criterion variable was a 20-item multiple-choice exam with five possible answers per question given to all students immediately after they read the passage and again exactly four weeks later. Presentation strategy groups were contrasted against a reading without questions group. Four of the six groups reading with questions at the beginning of the paragraph scored higher on the test given immediately after the reading than the group reading without questions. There were no significant differences among any of the group scores for the test given four weeks after reading. Data were also subjected to multivariate, repeated-measures analysis which revealed significant differences between groups on the linear component of paired test scores for each group. Pair-wise contrasts for differences in linear trends in test scores between the group reading with no questions and each of the other six groups revealed two significant differences. Scores for the group reading with unhighlighted questions dropped significantly more than for the group reading with no questions, and scores for the group reading with plain questions which were set above the paragraph dropped significantly less than for the no-questions group. The researcher concluded that inserted questions in textual narrative did make a difference, but only for very short time periods. He indicated that presentation style such as position and method of highlighting the question might be important variables. He suggested that further research on questioning strategies as reading aids was certainly warranted, especially in view of the existing emphasis upon learning by textual reading in our schools and universities.

Speaker (1987) conducted a study to: (1) examine changes in retention of information from elementary science passages when readers were required to elaborate and predict overtly as opposed to when they process covertly; (2) examine the effect of chunked presentation of text (in phrases, t-units, paragraphs) versus unchunked presentation (page at a time) on retention of information; (3) examine the effects of processing strategies on retention; (4) analyze the strategies used during overt processing; and (5) analyze the effects of the experimental conditions on student performance as measured by typical teacher-made tests. Thirty-two (32) average or above average sixth-graders read and orally recalled passages on amphibians and reptiles that were based on a sixth-grade textbook. Subjects participated in two processing conditions and were randomly assigned to one of four presentation conditions. In the experimental processing condition subjects read a chunk of text and responded orally to probes which reqeired overt elaboration and prediction before the next chunk of text was presented. The other processing condition controlled for the chunked presentation of the text. In the presentation conditions, subjects read text in phrases, t-units, paragraphs, or pages. The rationale for the study predicted that over processing would lead to superior recall of information from text and that the enforced processing of smaller text chunks would enhance retention. Retention was measured by counting the number of propositions recalled after reading. Results indicated that retention in the overt processing condition was significantly superior to retention after non-overt processing only in the phrase presentation condition with micro-level propositional results. No effects were observed for presentation chunk alone or for macro-level propositional recall. Recall of information in the predictions of the subjects was superior to their micro-level propositional result. Strategies used by the readers during overt processing included (1) rehearsal loops; (2) elaboration with personal experiences; (3) analogy; (4) elaboration with conceptual information; (5) asking the experimenter; (6) slot- filling; and (7) schema-based prediction.

Using the notion of selective attention, that increased importance leads to increased attention which leads to increased learning, **Reynolds and Baker** (1987) examined how graphical representations influenced what was learned and recalled from text. Results highlighted the importance of graph-focusing strategies for text learning, thus supporting the creative use of interactive computer presentations. One hundred thirty (130) ninth graders, 65 males and 65 females were randomly assigned to one of the five following treatment groups: (1) text presented without graphs in a booklet; (2) text presented with static graphs in a booklet; (3) text presented without graphs on a computer; (4) text presented with static graphs on a computer; and (5) text presented with interactive graphs on a computer. Spatial ability as well as comprehension of concepts, recall of facts, and applications from reading were measured. Attention was evaluated through a questionnaire. Results supported the notion from earlier research that texts with and without graphs draw similar amounts of attention and produce similar amounts of learning. Also, computer presentation of text enhanced attention and learning compared to normal presentation of text. Moreover, interactive graph presentations increased attention to the task but had no effect on learning. The authors concluded that their results supported selective attention hypotheses.

Diebold (1987) compared the effects of verbal and pictorial information within printed instructional formats on science concept learning by hearing impaired students. Deaf students, 12 to 22 years of age, were assigned to one of four groups: (1) standard text format; (2) simplified text format; (3) simplified text/labeled diagram format; or (4) labeled diagram format in a pre-test-post-test design. All instruction focused on the water cycle and the carbon dioxide-oxygen cycle. Analysis of the gain scores showed that students in the simplified text/labeled diagram and the labeled diagram formats made significantly higher mean gain scores compared to the standard text format. Gain scores in the simplified text format were not significantly different from the other three formats.

Seeking to delineate the interplay of reader and text, **Baldwin** (1987) investigated the influence of reader factors, topic knowledge, macro-organization of text, and rhetorical pattern on recall of science passages written in an expository style. Using fifth graders in a mixed design study which had two phases, preparatory and recall, Baldwin found that macro-organization and topic knowledge had separate influences on total recall. Pre-test to post-test gain in topic knowledge was affected by macro-organization. The author found mixed results as to whether more topic knowledge could aid in total recall when reading a poorly organized passage.

3.32 What effects do devices such as concept mapping and advance organizers have on students' acquisition of knowledge and skills?

Concept mapping, a heuristic first introduced by Novak, continues to be used by researchers in their quests to understand learning. **Bodolus** (1987) reported a thesis study on the use of concept mapping to facilitate meaningful learning in science for ninth grade students. A pre-test-post-test control group research design was used. Four hundred twenty-nine (429) students were assigned by computer to one of four science classes. Each class was then randomly assigned to one of three groups: (1) an experimental group that received the mapping process; (2) a traditional group that received the 'traditional' teaching strategy; and (3) a control group that was denied both the experimental and traditional treatments. Analysis of content post-test scores showed that the experimental and traditional groups outperformed the control group, but that no difference existed between the mapping and traditional groups. Males outperformed females on the mapping process, but females revealed more improved attitudes toward science.

Heinz-Fry (1987) evaluated concept mapping as a tool for meaningful learning with college biology students. An experimental group which utilized concept mapping for three units was compared with a control group which used traditional study methods in an auto-tutorial college biology course. Results of the five month study revealed no significant differences between the groups on knowledge acquisition, retention, and learning efficiency. However, significant interactions between SAT score and group membership were found. The results indicated a tendency for high SAT control students to outscore high SAT experimental students on the initial test; this situation was reversed on the post-test. Low SAT subgroups revealed no such differences. Students reported that mapping increased their integration of knowledge, aided in grasping material, clarified connections among concepts, and helped them devote less time in memorizing.

Advance organizers, first introduced by Ausubel, were used in three studies. **Lewis** (1987) compared the effectiveness of an Ausubelian advance organizer and simplified readability of science content when used together or separately in the biology laboratory. The criterion measure was a content examination. Ninth grade students in eight biology classes were randomly assigned to treatments. The equivalence of all classes was determined by the application of a pre-test and reading scores from the California Achievement Test. To test the effects of an advance organizer, introductory material was developed in accordance with Ausubel's theory. To test the effects of readability levels on student understanding and comprehension, two types of written laboratory procedures were developed for investigations covering ten weeks. One type was written at a reading level close to the grade level of the students; the other type was rewritten at a lower grade level without changing content. Readability levels were determined with the aid of two standardized readability formulas. The advance organizer groups received a written organizer at the beginning of class prior to receiving written laboratory procedures. Students then received one of the two types of written laboratory procedures. The control group received no organizer or simplified written laboratory procedures. Overall, the results indicated that either the advance organizer or simplified reading materials groups significantly benefited from the treatment, but the two treatments together were significantly better than either alone. In addition, a post study questionnaire distributed to all students did not find any significant differences in the expectations of the students for their performance when there was a change in reading levels of materials to be comprehended.

Carnes, Lindbeck, and Griffin (1987) reported research on the effects of incorporating advance organizers into CAI tutorial programs on the rate of learning, achievement, and retention of high school physics students who worked in different size groups. Results indicated that advance organizers had no significant achievement or retention effect. A significant effect was found for tutorial group size. Students who worked in groups of three and four showed significantly better learning rates than did students who worked alone.

Barron (1987) studied the relationship between contrasting advance organizers and achievement with students of differing sensory modalities and aptitudes. One hundred twenty-six (126) high school sophomores in five intact classes participated in one of four treatment groups: (1) visual-auditory-kinesthetic; (2) visual-kinesthetic; (3) auditory-kinesthetic; and (4) no advance organizer. The five-week treatment focused on dissection of animals. Results showed a significant effect for contrasting advance organizers on achievement, no effect of sensory modality preference on achievement, an effect of aptitude on achievement, and an effect for the matching of contrasting advance organizers with sensory modality preference on achievement.

Olarewaju (1987) reported a study which applied learning hierarchies to high school biology instruction. Results suggested that organizing learning tasks hierarchically significantly benefited the performance of students relative to a non-hierarchical organization of learning tasks.

The employment of a variety of writing, reading, and organizational techniques during instruction produced mixed results when compared to 'traditional' instruction. Biology students improved their short- and long-term retention of biology concepts when asked to use expressive summary writing rather than conventional note taking. The use of inquiry techniques in learning science vocabulary terms by elementary students was not significantly better than conventional drill and practice, but deaf students who used verbal and pictorial information (labeled diagram format) had superior achievement over counterparts who used the standard textbook usage. The use of overt processing strategies compared to non-overt processing indicated that students overtly processing had better retention of the material. In two studies no advantage was found for using concept maps to improve knowledge attainment, retention, and learning efficiency, even though in one of the studies the students consistently believed that the use of concept maps helped all categories. Two out of three studies found that the use of advance organizers improved learning. In one case the learning was further improved when coupled with simplified reading materials.

3.4 Methods in the Science Classroom

3.41 What is the effect of individualized instructional strategies on science learning?

Chiang (1987) studied the effects on the achievement and the growth of scientific ability of Taiwanese eighth grade students who were taught physics using an individualized instruction (II) format as opposed to those who were taught physics using conventional instruction (CI). Students in two secondary schools representing different geographical locations in southern Taiwan were selected to serve as subjects for the study. A pre-test-post-test-equalized experimental design was used, with data gathered from an IQ test, a reasoning ability test, a physics aptitude test, midterm and final achievement tests, and a follow-up test of the growth of scientific ability. Analysis of covariance using the reasoning ability and physics aptitude of students as covariates resulted in the following conclusions: (1) the II group was significantly superior to the CI group on the midterm and final achievement measures and in the growth of scientific ability; (2) among the slow learners the II group was significantly superior to the CI group on the midterm achievement measures; (3) among the average learners the II group was significantly superior to the CI group on the midterm achievement measures and the growth of scientific ability; and (4) among the fast learners the II group was significantly superior to the CI group on the final achievement measures.

3.42 What are the effects of alternative presentations of ideas on achievement?

Isekenegbe (1987) compared the effects of laboratory specimens and visual aids on fact and concept learning in high school biology. The content was related to the Phyla Arthropoda and Chordata. Forty-four (44) students in two high school biology classes were the subjects in the five-week experiment. Isekenegbe found no significant difference in the relative efficacy of laboratory specimens versus visual aids on the reinforcement of facts and concepts taught in the study.

Holquist (1987) compared the relative utility of traditional and alternate taxonomic keys of selected crustaceans from Mississippi Sound and nearby waters. The key variables were format (description and illustration) and sequence (dichotomy and polychotomy). College and high school students participated in the study, as did upper elementary school students on an informal basis. Holquist found that the illustrated format significantly increased the functionality of the key for all groups.

Traditional keys were found to be the least effective tools. The increase in functionality of alternate keys was achieved without loss of taxonomic validity.

Smith (1987) tested the effects of three traditional teaching strategies on the cognitive achievement of first year biology students. Subjects participated in lecture, laboratory, or an integrated combination of lecture and laboratory. Students were pre-tested and post-tested on critical thinking as well as biology achievement. Students in the integrated group achieved the highest post-test mean of cognitive achievement. There was no treatment effect on critical thinking. Regression analysis showed that pre-test scores were the best predictors of achievement post-test scores.

Anderson, Hostetler, and Okafor (1987) analyzed and compared the implicit and explicit structural components of secondary biology instruction. The authors found that the implicit structural dimension had higher continuity of thought, greater persistence of theme, and a lower progression density than did the explicit dimension. The average rate of change in explicit ideational content was about 2.3 times greater in the explicit dimension than in the implicit dimension. The authors proposed that research be conducted on how lessons based on implicit higher order themes affect the acquisition of cognitive skills.

Germann (1987) researched the effects of DIAL(SPS)2, a directed approach to learning science process skills. Students in two high school biology classes participated in 12 to 14 laboratory activities that were designed using the DIAL(SPS)2 model. Two control classes received the same basic biology instruction but did not participate in the DIAL(SPS)2 experiments. Results suggested that concrete thinkers benefited more from the experimental strategy, whereas their counterparts with more advanced cognitive capabilities benefited more from the control instruction.

3.43 What is the effect of cooperative learning on achievement?

Merebah (1987) compared the effects of a cooperative learning method called Teams-Games-Tournaments (TGT), and the Traditional Teacher-Centered (TTC) method used in schools in Saudi Arabia on the science achievement, attitudes, and social interaction of students in class. A random sample of seven intermediate schools in Riyadh was selected. In each of the seven schools, a science teacher was randomly selected from the pool of science teachers, followed by random selection of two of each teacher's intact classes. In each school, the two classes were assigned randomly to the experimental or control group.

Teachers were trained to use TGT. The topic covered during the eight week study was a unit on force and motion. The TGT work sheets and the game sheets were developed by the investigator. Pre-test and post-test data were gathered via an achievement test, an attitude questionnaire, and a sociometric questionnaire. Data analyses via ANOVA and MANOVA led to the following conclusions: (1) TGT cooperative learning method was significantly more effective than the TTC method in enhancing science achievement; (2) TGT method enhanced science achievement of classes of different abilities (high, average) more than TTC did; (3) both TGT and TTC classes showed positive attitudes on their attitude pre- and post-tests, but there was no significant difference between their attitudes on the pre-test or the post-test; and (4) there was no significant difference between TGT and TTC classes on mutual attraction and helpfulness.

3.44 Do students view science process skills similarly to experts?

Tamir and Amir (1987) performed a factor analysis on test results of Israeli 12th grade biology students and found seven laboratory process skill factors: (1) handling quantitative relationships; (2) explaining and assessing data; (3) conceptualizing and planning investigations; (4) summarizing results; (5) interpreting and concluding; (6) selecting form of presenting findings; and (7) designing experiments. They found that some process skills which had seemed closely related were actually separate factors. For example, conceptualizing investigations and designing experiments were separate. They recommended explicitly teaching these skills, rather than hoping they will just 'happen' as a consequence of lab experience.

A wide variety of instructional strategies was tested in 1987. One study reported that in the high school physics classroom an individualized instructional strategy was superior to conventional instruction for the mid-term examination, final examination, and growth of scientific ability scores. In another study, it was shown that when conventional biology students received a directed approach to learning process skills, there were differential positive gains in learning. The reverse was found to be true for formal operational students who responded best to conventional instruction. Still another study found that elementary students participating in the cooperative learning model gained more science content than in the conventional elementary classroom. The above findings are useful in that they support the notion that strategies which pay attention to the needs of the individual tend to have positive payoffs, but, on the other hand, they all represent the classic kinds of studies that have come under negative scrutiny by science education researchers. Serious questions need to be raised about these types of studies. There is little specificity about the independent variables, which are defined in very global terms. The dependent variable is typically science knowledge, probably the least interesting variable to study. The study which best typifies the point compares lecture alone to laboratory alone or a combination. Of course, the combination has the most positive impact on achievement, but why? This is the next step research needs to take, assessing the underlying and specific common elements in many of these instructional strategies and how they relate to specific learning outcomes. We need to stop comparing apples and oranges.

3.5 Curriculum Development, Content, Objectives, and Evaluation

3.51 What factors influence and what processes compose the development of curriculum?

Johnson (1987) conducted a survey concerning biological concepts that should be included in an introductory college biology course. A list of 114 concepts developed at the University of Wisconsin in 1970 and a questionnaire were sent to a national sample of 340 randomly selected community college, senior college, and university biology teachers. The survey asked them to rank the importance of including the concepts in an introductory college biology course and to add other concepts that should be included. The results were analyzed to determine the degree of agreement between the current study group and the university biologists in the Wisconsin study (**Thompson**, 1970). There was 57% agreement between the two groups on the 30 highest ranked concepts. Additional concepts submitted did not indicate a significant change in the emphasis on biological concepts resulting from recent advances and discoveries. The author recommended that the concepts identified in this study should be used in future curriculum development, that a common definition of the term 'concept' should be developed, and that studies should be undertaken to identify concepts resulting from recent discoveries which should be included in introductory biology courses.

Blystone (1987) reported a study that examined the use of results of standardized placement examinations for pedagogical purposes. Using 250 tests, he examined student responses to questions in the May 1984 Biology Advanced Placement (AP) Exam that related to cell structure. Interviews concerning these responses were conducted with high school science coordinators, readers of the 1985 AP Biology Exam, AP biology teachers, college biology teachers, and research cell biologists. Textbooks and resource materials were examined for inclusion of material on cell structure. Blystone recommended that results from standardized placement exams could be used in certain cases in curriculum development and could assist in the development of hierarchically related science textbooks from high school to college.

Mundangepfupfu (1987) analyzed how magico-traditional and scientific beliefs were distinguished in discussions of science curricula in Africa. The author sought to determine what should be taught in science in magico-traditional cultures and how it should be taught. Two major concepts were used in the analysis. The first was that scientific beliefs reflected a different world-view from that reflected by magico-traditional beliefs. The second concerned belief systems, namely evidential and non-evidential. The author argued that students could learn science without rejecting magico-traditional beliefs, because the two were understood through different belief systems. The author also suggested that an understanding of the distinction between scientific and magico-traditional beliefs was important for the development of science curricula for use with students who have grown up in a magico-traditional culture.

Williams (1987) studied the processes by which the Curriculum and Instruction Advisory Committee of the Texas Learning Technology Group reached decisions on the development of a physical science curriculum to be delivered by interactive videodiscs. He demonstrated that the processes were influenced by research, tradition, politics, state mandates, school district and personal philosophies, and teacher and student needs. The core curriculum being delivered was to include remediation and enrichment loops and laboratory simulation. Participants indicated that students should conduct regular laboratory experiments in addition to viewing simulations. The curriculum also included the possibility that the course might be taught by persons not certified in physical science.

3.52 What is the content of elementary science textbook series?

Staver and Bay (1987) studied commonly used elementary science texts using the Project Synthesis goal clusters for a major part of the examination. Eleven textbook series, representing about 90% of the national market, were analyzed. One primary (K-3) and one intermediate (4-6) unit were selected for analysis throughout the eleven series. Text materials, illustrations, and activities/experiments were analyzed and classified as: (1) academic; (2) personal; (3) career; or (4) societal in focus. Results showed that most text prose and illustrations focused on academic science. Most of the remaining prose and illustrations focused on the personal goal cluster.

The career and societal clusters received very minor attention. Activities/experiments were almost entirely academic in orientation, and only minor space was devoted to them. When activities/experiments were analyzed as to being confirmation, structured inquiry, guided inquiry, or open inquiry; almost none were found to include any inquiry. The authors discussed the implications of the results and compared the results with National Science Teachers Association recommendations.

Hamm (1987) and **Hamm and Adams** (1987) studied the extent to which fifth and sixth grade science textbooks dealt with the global issues of war technology, world population, world hunger, water resources, and air quality. National and international surveys of scientists were used to identify these issues as important to the future of the planet. Five raters examined ten top-ranked textbooks to determine pages of content devoted to each issue, depth of coverage of issues, and differences in grade level. Less than 2% of the 4,383 pages examined were devoted to the above issues. Most of the content related to population, water resources, and air quality. The least content emphasis was on war technology. No significant differences were found among textbook series or between fifth and sixth grade levels. The authors concluded that the most widely used textbook series avoided serious discussion of major global problems.

3.53 Does ISIS serve the needs of non-college bound students?

Clevenstine (1987) used Bloom's Taxonomy of Educational Objectives to analyze the performance objectives and test items found in the 33 mini-courses and criterion-referenced tests in the Individualized Science Instruction System (ISIS). Results showed that the ISIS mini-course objectives and test items were written primarily at the lowest two of Bloom's six levels, Knowledge and Comprehension. The author cited this as evidence that the ISIS materials served the needs of non-college bound students for whom they were designed. Chi-square analysis of ISIS materials showed a positive relationship between performance objectives and test items in 24 of the mini-courses and a negative relationship in the other nine. This indicated the need for re-evaluation of the tests in the latter mini-courses.

3.54 What is the content of college level general biology and geology?

Winkler (1987) conducted a survey of the content of general biology courses taught in two-year colleges in Alabama and of the background and attitudes of the instructors. His results included information from questionnaires returned by 51 full-time and 11 part-time instructors. The average age of the full-time faculty was 40. Their average number of graduate level course hours in biology was 40, with the major concentration in zoology. He concluded that traditional biology topics were given moderate to major emphasis by 50% of the respondents. Molecular and cell biology were most frequently identified as receiving major emphasis. Almost all of the topics taught were selected on the basis of pure science, with little consideration given to occupational preparation or societal concerns. More than half of the respondents reported that ethical and societal concerns were considered in their courses, but only 20% reported that these topics were given moderate to major emphasis. A majority felt that inclusion of topics was influenced by requirements of students seeking transfers to other colleges. Almost all felt that a need existed for state-wide coordination of course content.

Barrow and Germann (1987) conducted a survey among science teachers who had shown interest in teaching about acid rain by requests for materials or attendance at workshops. Of the 202 surveys sent out, 71 were returned. Of the teachers returning surveys, 42 had taught about acid rain during the previous year. Approximately one-third taught in grades 1-8, one-half in high school, and one-sixth in post-secondary schools. The results indicated the topics that teachers believed were the most important in teaching about acid rain, specific laboratory exercises that teachers used from a resource guide, and choices made by teachers for types of resource materials if they were available.

Howe (1987) reviewed 31 introductory geology textbooks and found that the concept of contact between bodies of rock was seldom discussed. He indicated that 15 terms related to the concept of contact were usually inadequately covered or omitted. He strongly urged introductory textbook authors to provide greater coverage of geological contact and related terms.

3.55 What objectives should guide environmental education?

A descriptive literature review was performed by **Hammerman and Voelker** (1987) who reported the establishment of a set of research based objectives to guide policy and curricular decisions with respect to environmental education. The authors noted two studies that were crucial to the advancement of environmental education concerns: The **Tsilbi Declaration** (1978) and **Hammerman** (1979). The first study established five consensus environmental education areas from which to derive objectives:

(1) awareness; (2) knowledge; (3) attitudes; (4) skills; and (5) participation. The latter study utilized a Delphi technique to establish a research based set of objectives through concordance among environmental scientists.

3.56 Is hands-on science more effective than textbook-based science?

Shymansky, Hedges, and Woodworth (1987) repeated earlier meta-analysis studies, originally reported in 1983, on the impact of science curricula developed in the 1960s and 1970s on the performance of students. Earlier results were reexamined using newer statistical procedures, because it was thought that some earlier findings might have been misleading. This re-analysis generally supported the earlier work, which concluded that the new science curricula of the 1960s and 1970s were more effective than traditional textbook programs of that time. However, using the refined methods, only four of the criterion cluster effects were significantly positive compared to all seven in the earlier work. The authors reported that fewer than 33% of the analyzed studies described whether or not teachers received training prior to or during the study period. They suggested that, in most cases, training did not occur and considered this a serious omission. They also suggested that science curriculum developers could help the cause of science in schools by building in ties with reading and mathematics skills.

Phillips (1987) studied the influence of the Pennsylvania Department of Education elementary science inquiry curriculum on the formation of positive science attitudes in students and teachers in grades 1 to 4 and compared this to students and teachers in the same grades who used a textbook science curriculum approach. The study included 341 students and 24 teachers. Approximately one-half of the students and three-fourths of the teachers were in the inquiry curriculum group. The survey instrument was the Phillips Adaptation of the Allen-Allison Attitude Scale for Science, Scientists and Science Careers. A variety of statistical analyses were applied to the data. No differences were found between students and teachers in the two groups in grades 1 and 2. However, both students and teachers in grades 3 and 4 using the inquiry curriculum showed significantly more positive attitudes toward science than their counterparts using a textbook science curriculum. Results also showed no significant gender differences in attitudes toward science among students.

Griffiths (1987) reported a pre-test/post-test control group study on the effect of activity-based science instruction compared to a text-recitation approach for third and sixth graders. Instruction lasted for a twelve week period, and the results revealed a significant difference in achievement at both grade levels in favor of the activity-based group. There was, however, no significant effect for teaching method on a test of critical thinking.

3.57 What is the status of 8th grade earth-space science instruction in Alabama?

Hall (1[illegible] reported on the status of earth-space science instruction [illegible]ne eighth grade level in Alabama public schools. Questionna[illegible] were sent to principals and teachers at 213 randomly selected schools, seeking information concerning classroom facilities, curriculum, and the education and certification of teachers. The results showed deficiencies, particularly in the areas of facilities, curriculum content, instructional materials, and laboratory and out-of-class activities. Respondents indicated that only 12% of their undergraduate and 8% of their graduate course hours were in earth science. Only 3% were certified in earth science or geology. Most were certified under general science endorsements. The report included a variety of recommendations for changes and areas for further research.

Carey (1987) conducted a survey of college geo-science departments concerning (1) current budget problems; (2) poor job markets for graduates; (3) geo-science majors with inadequate technical writing skills; and (4) teaching geo-science to non-science students. One-third of the respondents indicated that their graduates had inadequate technical writing skills, but none cited this as a major issue facing geo-science education or geo-science departments. Writing assignments in geo-science courses and technical writing courses taught by other departments were rated as the best methods to improve writing skills. Almost two-thirds of the respondents believed that their teaching programs for non-science majors were successful. Surprisingly, when teaching non-science students, faculty placed more emphasis on geo-science concepts than on practical aspects of geo-science in society.

3.58 How do the views of society influence curriculum and instruction?

Fraser-Abder (1987) presented an analysis of parent, student, and teacher opinions of elementary science teaching in Trinidad and Tobago. The results of surveys indicated that most parents, students, and teachers thought that the curriculum was interesting, exciting, and effective. The greatest concerns about teaching science were expressed by teachers with poor science training.

Al-Korashi (1987) reported a study of constituent group perceptions of the effectiveness of the Math and Science Centers Program of the Educational Ministry of Saudi Arabia. Questionnaires were sent to 50 graduates of each center, 80 faculty members in the centers, and 40 principals of intermediate schools. Results showed that graduates, faculty, and school principals had similar views of the centers. They agreed that, in general, the centers were improving the training of intermediate school math and science teachers. The areas of evaluation and research were judged to be the weakest in the centers. There was agreement that more sophisticated laboratory equipment and additional library resources were needed. More flexibility was recommended for study and course scheduling. Faculty in the centers rarely used innovative teaching techniques, which indicated a need for more in-service professional development opportunities. Recommendations growing out of the study were to develop more specialty courses and to incorporate more innovation into the teaching conducted in the centers.

Dreessen (1987) studied the impact of the life and works of Rene Dubos (1901-1982) on the public understanding of science. The study included information concerning his early years in France, his time with the League of Nations in Rome, and his immigration to the United States in the 1920s. Dubos' role in the public understanding of science did not begin until after his 1950 publication of a biography of Louis Pasteur. By the 1960s he was well known to many as a leader in the new environmental movement. By the 1970s some of his attitudes brought him into conflict with many in the environmental movement because his philosophy respected the human need to change the natural environment. Dubos' publications were often praised for their clarity and the timeliness of their topics. He reached the general public directly through articles in many popular periodicals, many speeches, and occasional TV appearances. Indirectly, the public felt his influence because of the impact his philosophies had on important people and organizations. Appendixes in this study included extensive lists of his books and his non-technical articles and interviews.

Durrant (1987) published a study that attempted to answer the following question for the academic discipline of geomorphology, 'How should the discipline respond to increasing internal and external pressure to become more socially relevant?' He indicated that many of the published comments on this topic were divided between those who believed that academic disciplines should maintain a disinterested position in their research, and those who would direct research toward the solution of practical problems outside the domain of pure science. He claimed to have developed a scheme for distinguishing pure from applied research based not on methods but rather on differences in immediate goals. He pointed to the obvious conflict between the pure and applied sciences in times of limited funding and attempted to place this debate in a broader context of history and society. He suggested that the best approach for academic geomorphologists deserving more involvement in society was for them to take a disinterested but persuasive position based on reaching others through teaching, continued pure research, and improved communication of the results.

During 1987, researchers examined the goals, objectives, and content of the science curriculum from various philosophical, cultural, historical, and political perspectives. Two studies evaluated the college biology curriculum. The first surveyed colleges across the United States to evaluate a sixteen-year-old list of important biology concepts. It was determined that over one-half of the top one-fourth of the highest ranked concepts were in agreement over the time frame, and that these concepts plus those from recent scientific discoveries should serve as the basis for future introductory biology curriculum development. Another study asked instructors to assess the content of an introductory biology course. One-half of the instructors emphasized traditional biology topics, such as cell biology, with little consideration given to occupational or societal concerns.

Three studies in geology education pointed out curriculum deficiencies. A review of college introductory geology textbooks found that the important concept of contact between bodies of rock and fifteen related terms were seldom discussed or completely omitted. Another study found that college departments placed more emphasis on geo-science concepts for the non-science student than on the practical aspects of geo-science in society. A survey of Alabama earth science instructors indicated that only 3% were certified to specifically teach the subject.

A number of studies reported hands-on inquiry science to be more effective for influencing attitudes of students toward science and science achievement in specific applications at various grade levels. Concerns about specific training for teachers and linking hands-on science to enhancing reading and mathematic skills were raised.

Research and recommendations about science textbooks are in contrast with the approach taken by the primary textbook series for the elementary schools. Two studies analyzed major elementary science textbooks and found them to be heavily oriented to narrow science topics, avoiding for the most part other important aspects of schooling including integration across the curriculum (e.g., STS themes). One study concluded that the text prose and illustrations are focused on academic science and most of the activities/experiments are academic with very few inquiry in nature. Most of the remaining prose and illustrations focused on personal goals with very minor attention to career and societal topics. The other study found that important global issues such as war technology, population, hunger, water, and air accounted for only two percent of the content.

Also addressed was the importance of understanding how the conflict between magico-traditional (non-evidential) and scientific beliefs (evidential) of the Third World student can be addressed without rejecting the values and culture of students raised in the magico-traditional belief system. The author stressed that students should not be forced to give up one belief system and totally replace it with another. The two belief systems, though not compatible, are parallel and can be accommodated by the students. Another study addressed the various political influences on the decision to use interactive video discs as an attempt to insure that the core of a physical science curriculum was available to Texas teachers, whether or not taught by a certified teacher.

It is evident from the literature reviewed that the major driving force behind science curriculum continues to be content, content, and more content! Curriculum research in science education needs to stop documenting this deficiency and begin exploring the reasons why the curriculum is content-bound at all levels of instruction. Only when these variables have been identified and operationalized will the science education profession be in the position to affect real curriculum change. In science education, researchers need to exploit and apply the literature in generic curriculum and staff development to formulate viable models for integrating the instruction of activity-based science and interdisciplinary themes in the kindergarten through college curriculum.

3.6 The Development and Validation of Instruments

An assortment of instruments were noted in other sections throughout this review. It is our intention here, however, to report the development of new questionnaires, instruments, and surveys, where the research clearly indicated that such development was the primary intent of the study. It is also our intent in this section to examine research studies reporting the results of further validation, applications, or critical analyses of existing survey research methodology.

3.61 What new assessment instruments have been developed in science education?

A doctoral dissertation performed by **Smith** (1987) described the development of a science process skill assessment for elementary students. The purpose of the study was to construct a measure that was of specific application to fourth grade students. It consisted of the following processes: (1) observation; (2) classification; (3) inference; (4) prediction; (5) measurement; (6) communication; (7) use of time/space relations; (8) operationally defining; (9) hypothesis formulation; (10) experimentation; (11) variable recognition; (12) data interpretation; and (13) model formulation. An initial group of writing team participants generated 65 test items representative of the process skills listed above. Content validity was determined by a panel of science educators, acting as expert judges. A 55-item Pilot 1 instrument was administered to 184 fourth graders. Data analysis revealed a reliability coefficient of 0.73. A second revision resulted in a 40-item instrument, Pilot 2, which was administered to a different sample of 113 fourth graders. Other than basic content validation, however, no additional attempt was reported to assess the validity of the described measure. In addition, it was not clear either what forms of reliability were being reported or what the rationale was for the development of this instrument.

Mulkey (1987) reported the development of an assessment instrument that incorporated a sociological perspective to evaluate science textbooks. A rationale for the need to develop such an instrument centered on the hypothesis that textbook content for middle-class school districts and higher grades possessed an organizational structure more conducive to the intellectual and emotional characteristics of scientists than for working-class school districts. Application of this instrument yielded results that facilitated difference patterns in science textbook knowledge supportive of an enhancement of scientific literacy in contrast to knowledge supportive of scientific role development. The author concluded that the instrument required more extensive testing in other locales outside of New York State in order to assess its predictive validity.

3.62 Do existing assessment instruments validly measure attitudinal constructs, and what cautions should be exercised in interpreting attitudinal scale data results?

The following two research studies reported on perceived potential problems with respect to the development and interpretation of attitudinal data collection instruments.

Rennie and Parker (1987) illustrated the need to consider the structure of an instrument as well as the structure of the population being measured, if the interpretation of attitudinal scale data were to have true meaning. To provide evidence of such a problem, the authors examined attitudinal scale data collected from an instrument that was developed for specific use in a larger research effort. They correctly assessed that without performing factor analytic techniques, researchers run the risk of inaccurately assuming that a scale possesses unidimensionality. In other words, a significant alpha reliability coefficient as a measure of internal consistency and inferred to mean homogeneity could be insufficient. In a similar manner, they also proposed the risk of assuming that an intact group possessed homogeneity, simply as a consequence of its functioning together as a group. In an example, the authors suggested that researchers become more cognizant of potential systematic biases that exist within intact groups. One obvious source of bias was class membership in general terms, gender in particular application. The authors concluded by challenging researchers to ascertain scale dimensionality with greater caution as well as rigor. They further stated that, since gender-related differences were often found in subjects such as science, a gender by class analysis of variance might immediately alert a researcher to a potential mediating variable that should be incorporated within the research design and subsequent analysis.

In harmony with the previous review, **Gardner** (1987) voiced the concern that standard item statistics and internal consistency reliability were not sufficient verifications for the assumption of instrument unidimensionality. Further, he noted that conventional methods of attitude measurement ignored a potential ambivalence dimension. The concept of ambivalence challenged the underlying assumption that favorable versus unfavorable statements represented bipolar results. He asserted that 'bipolarity' could constitute two meanings, weaker or probabilistic versus stronger or deterministic. The author contended that although ambivalence may be related to bipolarity in the weaker (probabilistic) sense, it was logically incompatible in the stronger (deterministic) sense. Citing several example studies in application, Gardner argued that the standard item-to-total correlation as a measure of internal consistency and, hence, unidimensionality represented bipolarity only in the weaker sense. Further, he noted that such internal consistency reliability correlations should only be used as a criterion for determining whether a scale is not unidimensional. Moreover, when statistically significant item-to-total correlations do occur, researchers should investigate the dimensionality of instruments with other, more appropriate statistical procedures. He concluded that factor analysis should be employed to assess dimensionality and that if positive and negative statements loaded on independent dimensions, these items should be separately scored and analyzed as independent measures with other research variables under investigation.

3.63 What are the results of further tests on existing instruments?

The five research studies reviewed below represent further validations of existing instruments, context applications, and confirmations or extensions of construct validation for several previously developed measures.

Kahlili (1987) performed a cross-cultural validity study of a science attitudinal measure, the Test of Science Related Attitudes (TOSRA), developed in Australia by **Fraser** (1978). The TOSRA was a seven-subscale Likert-type instrument, possessing 70 items. In the present study, 336 students from three suburban high schools in Chicago were administered the TOSRA during the last month of the academic year. Results indicated a confirmation of internal consistency reliability coefficients obtained by Fraser in the original validation procedures; however, the discrimination indices were, with the exception of one subscale, found to be very low. A subsequent factor analytic solution produced results that were also inconsistent with the original seven subscales. Instead, the present study findings indicated that the final three subscales could be collapsed into a single subscale. The author concluded that the distinctiveness of TOSRA subscales to measure seven attitudinal components was not supported by the results of the present study.

Ahlawat and Billeh (1987) conducted an analysis of the comparative psychometric properties of three tests of logical thinking. These three tests, the Longeot Test, the Classroom Test of Formal Reasoning (CTFR), and the Test of Logical Thinking (TOLT), were selected because they all purport to measure, in paper and pencil format, several modes of formal reasoning as they were originally delineated by Piaget. The sample population for this research effort consisted of 908 eleventh grade science students. Two hundred twelve (212) students were administered all three tests, while 696 took only the Longeot Test and the CTFR. The sequential order for test administration was randomized across all sections of students participating in the study. Results indicated that reliability coefficients for tests analyzed independently as well as in combined form were judged to be satisfactory. The concurrent validity correlations were, however, judged to be inadequate. For example, TOLT correlated poorly with all parts of the Longeot Test. Hypothetically, TOLT should correlate more closely with CTFR, but an obtained correlation coefficient of 0.43 explains only 18% of the common variance. The authors concluded that a specific measure of formal thought could independently possess respectable internal consistency, but the generalization of any individual test for a specific application might be suspect. They suggested that several prerequisite determinations be performed prior to making a decision regarding the use of a specific test for a given population sample.

Hutchinson and Barton (1987) examined the use of answer-until-correct tests to confirm a quantitative assessment of partial information. The results, based on a sample of 387 secondary student responses, indicated that a mechanical reasoning answer-until-correct test, yielded similar findings to a spatial reasoning test.

Another study, performed by **Baird and Borich** (1987), investigated the validity considerations relative to the integrated science process skills and formal reasoning ability. They examined the convergent and discriminant validity of two tests of science process skills, the Test of Integrated Process Skills (TIPS), and the Process Skills of Science Test (PSST), as well as two tests of formal reasoning, the Group Assessment of Logical Thinking (GALT) and the Classroom Test of Formal Reasoning (CTFR). All four tests were administered to a volunteer group of 54 pre-service elementary education majors enrolled in three educational psychology classes. Results failed to indicate that tests of integrated science process skills and formal reasoning ability actually measured unique traits; for example, 27% shared variance was indicated between the TIPS and GALT tests, and 38% shared variance was reported between the CTFR and PSST tests. The authors suggested that future research should attempt to identify means to enhance reasoning ability, with specific emphasis on aspects of reasoning essential to science process skill development.

3.64 What implications does technology have for large scale testing programs?

Bennett and Whittington (1987) reported on the implications of new technology for College Board Mathematics and Science Achievement Testing Programs. The growing use of technology in high schools and colleges posed complex problems for College Board achievement testing programs. First, the content of Advanced Placement (AP) and Admissions Testing Program (ATP) mathematics and science tests should be compared to major curricular trends to identify topics that need to be better represented in the tests. A second line of inquiry concerned the implications of permitting the use of calculators on AP and ATP tests. Previous research found that the use of calculators slowed the rate of student response on some types of mathematics tests, implying a need for adjustments in test timing. Other research suggested that test scores could suffer negative effects, particularly when students were unsure when to use the device. Most importantly, the potential for differential effects on minority students should be explored. A final area of concern was the relative lack of content testing laboratory techniques and procedures within the AP and ATP science tests. This shortcoming was particularly apparent given the growing availability of laboratory simulation and experimentation software. Developing and pilot testing a laboratory simulation might provide testing programs with invaluable insight into the potential of such measures for assessment and the practical, technical, and policy problems they pose.

The majority of the studies reviewed reported concerns regarding a general lack of appropriate applications of psychometric theory with respect to validation parameters. This was particularly evident for conclusions examined relative to the interpretation of attitudinal instruments. The major concern with such instruments was the need to appropriately make use of factor analytic techniques for the purpose of determining the dimensionality of a given measure. Not only do science educators need to become more systematic in assessing the validity of specific instruments, but additionally, they need to be more cognizant of the existence of other instruments which may be more applicable within a given research context. As an example, the development of yet another measure of process skills might be perfectly legitimate; however, if such a development was conducted without a prior examination of already existing instruments, then the new measure becomes an exercise in how to put an instrument together rather than a true generation of new knowledge. If indeed an instrument with acceptable validity exists and is applicable in the given research context, then it should be used in preference to the development of another instrument that must itself undergo a rigorous treatment of reliability and validity.

4.0 CONTEXTS AND SETTINGS

The final commonplace represents the contexts and settings within which educational endeavors occur. The studies reviewed in this section examine and describe learners and learning, teachers and teaching, and curriculum and instruction, but they emphasize more so the contexts and settings for these activities. We begin with research that focuses on classrooms. This is followed by scholarship whose context is mass media. Next comes research done in informal educational settings such as museums, zoos, and aquariums. After that, research in field-based settings is reviewed. Finally, we conclude our review of research in science education with a review and discussion of national contexts and settings, with particular focus on two articles, one by Yager and Penick and the second by Linn.

4.1 Classroom Settings

4.11 What are the effects of video-based macro contexts on problem solving?

Sherwood, Kinzer, Bransford, and Franks (1987) conducted two experiments to assess the role of providing video-based macro-contexts in classrooms for helping students acquire science information in a way that enabled them to remember it and use it as tools to solve subsequent problems. The video segments that were used involved popular films such as "Swiss Family Robinson," "Raiders of the Lost Ark," and "Star Wars." These films were used in videodisc format since videodisc could be computer-controlled, allowing almost instant access to any segment of a videodisc and creating much richer opportunities for instruction than were possible with more traditional technologies. The results of the two experiments provided evidence that the use of semantically rich macro-contexts could produce increases in learning. In Experiment 1, with classroom students and science-based textual material, a short intervention of video segments and organizing questions yielded positive results when compared to simple reading of materials. Students in the video group were able to answer more questions about science content than were those in the passage only group. In Experiment 2, the use of organizing questions that related science information to the video context facilitated the ability of students to free recall science information and increased the probability of students using that information to solve a new problem that they faced. The results suggested that more sophisticated uses of technology, especially computer-controlled interactive videodisc technology, could have even greater benefits on comprehension and learning in science.

4.12 What are the natures of the roles and interactions of students in the classroom?

Tobin and Gallagher (1987) examined whole class interactions of students by observing 200 lessons in grades 8 through 12 in two urban Australian high schools. The authors found that a small number of 'target students' monopolized whole class interactions. Target students were usually male, asked more questions, were asked more higher level cognitive questions, and received higher quality feedback from the teacher. Target students were classified into two groups. The first group included students who self-initiated participation in classroom interactions and accepted the responsibility for personal academic achievement as well as for interaction with others. The second kind of target student participated when chosen by the teacher and tended to possess higher formal reasoning ability and higher achievement level compared to others in the class.

McLellan (1987) examined the social and contextual impacts of a computer simulation on students in a high school astronomy class. Utilizing observations of the interactions of student dyads, interviews with students and teachers, and an analysis of the simulation "Sky Travel" and related sources, she found that students assumed different roles. Student partners who had little direct computer interaction more often requested help and more often demonstrated off task behaviors. Student partners who dominated computer command entries gave help more often than they asked for help. Student interviews revealed that most subjects responded positively to the computer lab assignments, to "Sky Travel," to their partners, and to their teacher. The author suggested that "Sky Travel" and similar software could augment teacher resources for curriculum design and instruction. Further, she made recommendations for linkages between learning resources, social interaction in computer learning environments, roles of teachers in computer learning environments, and the interactivity of computers.

4.13 What are the perceptions of students with respect to their classroom environments and their teachers?

Gooding, Schell, Swift, McCroskery, and Swift (1987) reported a study designed to describe perceptions of students within high school classes in biology and chemistry over the course of a school year. The research focused on person-environment congruence, defined as the measure of the distance between perceptions of self and the science class, science teacher, and the subject studied. Four hundred ten (410) high school college preparatory science students responded to a questionnaire on attitudes toward and perceptions of the classroom environment. Responses revealed that science attitudes became worse during the school year. Two thinking variables, one involving creative exploration and the other involving logical thinking, decreased according to perceptions during the year.

Lawrenz (1987) compared the classroom environments perceived by fourth grade, seventh grade, and high school boys and girls in classes taught by male and female teachers to see if any perceptual differences existed. Three two-factor MANOVAS (teacher gender by student gender) showed no differences for fourth grade students, one for seventh grade students, and three for high school students. The seventh grade boys and girls perceived classes taught by females as having more friction than classes taught by males. High school boys and girls perceived classes taught by females as being more difficult than classes taught by males. Further, for the high school students it appeared that classes were perceived more favorably when the opposite genders were combined. The author speculated that these perceptual differences combined with role modeling could contribute to the lack of women in science.

Chevalier (1987) investigated questioning behaviors and perceptions of students using naturalistic methods to determine the frequencies and types of questions by gender and achievement. Over 80% of the 440 public questions asked by students during 2,889 minutes of observation were asked with permission, were student initiated, were answered, and received neutral feedback. Over 90% were responded to by teachers and were about content or procedures. Over 70% were asked to gain information and were lower level cognitive questions. High achievers asked significantly more questions than did others. Student interviews showed that students perceived low achievers as asking questions most frequently, followed by average, then high achievers. Ninety-seven percent (97%) reported asking questions because they did not understand, and 82% reported that they sometimes did not ask questions for various reasons such as embarrassment or being labeled as dumb.

Vargas-Gomez and Yager (1987) compared student attitudes concerning their science teachers at third, seventh, and eleventh grade. Samples of students were drawn from those enrolled in National Science Teachers Association (NSTA) exemplary programs and other students drawn from classrooms of a random selection of teachers who were also NSTA members. Some of the affective items from the Third Assessment of Science, National Assessment of Educational Progress (NAEP), were used for the study. Results indicated significantly more positive attitudes of students from the exemplary programs in several ways: (1) pleasure with student questions; (2) desire for students to explore their own ideas; (3) liking of science (at the elementary school level); and (4) ability and knowledge of science to make it exciting.

Working on the knowledge that process-oriented classes surpassed the more traditional methods of science instruction that are preferred by science teachers, **Dryden** (1987) investigated a model of classroom interactions from the theoretical viewpoint of the process environment. The IEA had measured: (1) the teacher; and (2) the matching science class students; so that it became possible to hypothesize a structural model for classroom environments using both sets of data. The partial least squares method was used to develop and test three models for classroom interactions. The results showed that attitudes toward school affected student aspirations and attitudes toward science. Also, the largest effects on science achievement were verbal ability, home background, and gender. Moreover, aspirations and attitudes toward science also had an effect on science achievement. The results further indicated that the effect of the teacher was mediated through the classroom process variables. Thus, the key was not the teacher, but the ability of the teacher to organize meaningful learning experiences for the student.

4.14 Is the science classroom a safe learning environment?

Hagelberg and Dombrowski (1987) reported a survey of safety and school accidents in Arizona schools. A total of 728 questionnaires were mailed; 314 were returned. Fourteen (14) were judged unusable, as they were not completed. Within the return group were 242 teachers and 58 supervisors. The results indicated that accidents occurred at a rate of 4.93 per week. Cuts and burns were the most frequently reported injuries. Accidents involving eye injuries ranked in the top five. Accidents not involving injury occurred at eight times the rate of injury related accidents. Chemistry students reported more burn accidents, whereas biology students had more preservative splashes. Little difference was found in the accident rates of male and female teachers. Moreover, little difference in the accident rate existed for varying levels of education. However, a difference did exist when age and years of experience were considered together. Fewer accidents occurred to students in classes of the youngest and least experienced teachers as well as the oldest and most experienced teachers. Students in classes of teachers of mid-range age and experience had the higher accident rates. Given the fact that 80% of the respondents had no specific training in laboratory safety, the authors recommended that safety education for teachers be required.

Increasingly, classroom interactions and the roles of students in the classroom environment are recognized as important factors in learning. Traditionally, research examining classrooms has focused primarily on teachers. However, as two studies demonstrate, researchers are now attempting to study students in the classroom setting, together with classroom resources such as computers. Understanding the interplay of teachers, students, and the environment is vital to understanding how learning takes place in classrooms.

The studies of perceptions indicate that student attitudes have a powerful impact on learning. Creative exploration, linear thinking, willingness to ask questions to clarify misunderstandings, and even long term career choices are all affected by student attitudes toward science. It appears that all too often these attitudes are negative. However, the results of the studies by **Vargas-Gomez and Yager** (1987) and **Dryden** (1987) suggest that science instruction can be designed to promote more positive attitudes and, thus, is likely to enhance learning of science. These studies suggest that the ability of the teacher to organize meaningful learning experiences and to utilize classroom processes that enhance affective dimensions of learning are keys to the development of positive student attitudes.

4.2 Mass Media Contexts

4.21 How does TV portray science and scientists, and what is the impact of such portrayal on the public?

Gerbner (1987) discussed the portrayal of science and scientists on prime-time television and assessed its impact on public conceptions of science. He reported that television cultivated a less than favorable orientation toward science and scientists. Prime-time television drama presented generally positive images and messages about scientists and science, but they were less positive than the images and messages about other professions. He suggested that portrayal of science deserved more focused attention by leaders in science, the community of scientists, and legislators since television reached everyone, not just people who sought out science education programs in museums and elsewhere. This meant that constant liaison was needed with those who write, produce, and direct television programs of all sorts, especially dramatic series. Gerbner recommended a science media coordinating council to plan strategy, streamline national media liaison activities, and organize meetings with network executives as well as the writers and directors who create most programs.

4.22 Can drama in the classroom modify attitudes?

McDonald (1987) investigated the use of drama as a means of changing student attitudes toward the evolution-creation issue in high school biology. A student production of the play "Inherit the Wind," which dealt with the Scopes Trial, was presented to the biology students attending two senior high schools in the suburbs of a major east coast city as part of their study of evolution. The students were divided into two groups, with 50% attending the play and the remaining 50% attending regular classes instead. Thurstone's Attitude Toward Evolution survey was administered to both experimental and control groups. To assess changes in attitude over time, the survey was readministered to the students six weeks after the presentation of the play. Gender and age of the students were used as blocking variables in the analysis of the results to determine the effect of these factors on the attitudes of the students who attended the performance of the play. Analysis of variance showed that the group of students who attended the play had a significantly more positive attitude toward evolution than did the control group.

These two studies point out the important role mass media such as television and theater can play, both inside and out of the school setting, in shaping understanding of scientific concepts and issues. The insights and recommendations of Gerbner concerning broadcast television deserve particular scrutiny since it appears that this medium now presents a less than positive orientation toward science and scientists that reaches a vast audience.

4.3 Museums, Zoos, and Aquariums

4.31 How do informal educational settings influence visitors to those settings?

Finson and Enochs (1987) reported on student attitudes toward Science-Technology-Society (STS) after visiting a science-technology museum. They examined the variable factors of the visitation that impacted student attitudes. Results indicated that significant differences in attitudes were present between visiting and non-visiting students and between grade levels.

Taylor (1987) reported a study of the behavior of family groups visiting the Steinhart Aquarium and assessed the relationship between visitor behavior and education in the aquarium. He found that a particular set of exhibits was almost always seen by weary visitors primarily due to a predictable traffic pattern through the museum. Also, visitors were unwilling to backtrack; thus, they missed some sections. Questions of visitors about the displays indicated an interest in concrete, literal, and visually verifiable aspects of the displays rather than abstract biological concepts. Their conversations centered on the theme of familiarity. They discussed the exhibits in terms of the things with which they had some previous experience. Time pressures felt by visitors were due to external factors (other things planned) and internal factors (being pushed along by the crowds in the galleries). Information flowed to aquarium visitors from three sources: (1) conversations among visitors; (2) direct observations of the displays; and (3) the label texts (in that order). The findings demonstrated that knowledge of trends in visitor behavior had direct application to the design of informal educational environments.

Churchman (1987) examined the potential impact of the Melbourne Zoo in Australia for recreational visitors. He used time as the major dependent variable. Specific goals included: (1) assessment of the potential cognitive and affective educational impacts of zoos on recreational visitors; (2) determination of the temporal and spatial patterns of the zoo visitors; and (3) improvement of the utility of nonreactive research methods. Data were collected on traffic density patterns, observations of 18 groups of visitors during their entire visits to the zoo, observations at 18 specific exhibits, and on feelings of 500 visitors about 11 exhibits from questionnaires. The mean time of visits at the Melbourne Zoo was 160 minutes, averaging 126 minutes walking among exhibits. It was recommended that both survey and nonreactive research methods be used in combination to cross-validate information on zoo studies.

The Explainer Program of the San Francisco Exploratorium was evaluated and explained in a report by **Diamond, St. John, Cleary, and Librero** (1987). The authors described in some depth the Explainer Program and summarized quantative and qualitative data collected to determine the effects of participation in the program on teenage students. Since 1969, nearly 900 students have been involved in the program. The results showed that participants developed increased interest in learning science, greater levels of self confidence, skills in getting along with people, and greater interest in attending college.

All of these studies suggest that informal educational settings such as museums, zoos, and aquariums can enhance understanding and appreciation of science. The studies by **Taylor** (1987), **Churchman** (1987), and **Diamond, St. John, Cleary, and Librero** (1987) indicate the importance of effective design of both physical layout and program design for optimizing the learning and appreciation of science engendered by visiting such sites.

4.4 Field-Based Learning Settings

4.41 What value does field-based learning add to achievement?

Lisowski (1987a, 1987b) studied the nature of ideas that students held about selected ecological concepts and investigated modes of instruction that would effectively help them gain an accurate understanding of their world. An experiential marine science field program served as the learning strategy for three independent groups of secondary students. The Student Ecology Assessment (SEA) instrument was developed as the means of obtaining information on understanding of ecological concepts. The effectiveness of the field instructional program was apparent in that specific concepts that were emphasized were learned and retained by the students. The mastery approach of learning in a field setting proved to be successful.

Griffin (1987) assessed two self-contained coastal geology field courses designed to increase: (1) content knowledge of coastal geology; (2) the perception of the importance of coastal geology topics; (3) confidence of participants in their ability to teach science of the coastal zone; and (4) the amount of coastal education incorporated into the classes of participants. Teachers who enrolled in the field courses entered with high levels of appreciation for the importance of coastal geology topics. Prior to taking the courses, teachers stated that they were incorporating 67% of the major topics. After completion of one course, they stated plans to teach 96% of the topics, and, after two courses, 88%. Mean cognitive scores averaged 38% prior to taking the courses, increasing to 67% after one course, and 87% after two courses. The results indicated that the field-based approach to teacher training in coastal geology was very effective in bringing about significant positive increases in attitudes toward and knowledge about coastal geology. Although one field course was sufficient to bring about highly significant gains in plans to teach coastal education and in confidence in the ability to teach science of the coastal zone, results indicated that both courses were necessary to achieve an acceptable level of content mastery.

Manner (1987) developed an environmental atlas of the Cuyahoga Valley National Recreation Area (CVNRA) for use by school groups on field trips to this undeveloped and scenic open space in northeastern Ohio. This atlas included base maps, a glossary, and explanations documenting topography, geology, soil, vegetation, wildlife, land ownership and use, history, water resources, and scenic vistas. The atlas also included suggestions for field trips and field studies.

4.5 The National and International Scene

4.51 Is a Science-Technology-Society theme viable in the science curriculum?

Bybee (1987) examined the description and justification of the STS theme as an integral component of the science curriculum. Using recent and current controversies over this issue as a starting point. Bybee described a conceptual framework for incorporation of STS and provides an historical perspective. Using noteworthy educational reports as a base and considering science education as a subset of education, Bybee delineated the strengths and weaknesses of opposing positions with respect to the role of STS as a force in shaping science curricula and built a case to support the STS theme in science education.

In a position paper, **Rubba** presented several perspectives on Science-Technology-Society instruction. He suggested that science curriculum should move away from a singular emphasis on academic preparation and give comparable weight to the development of abilities that students need to deal with science and technology as they interface with everyday life. Rubba pointed out that several exemplary programs have been developed based on an STS theme. Common among these programs is their involvement of students in hands-on problem solving investigations of STS issues. He concluded by stating that if we desire students to possess capabilities to act in a responsible manner on science and technologically-related societal issues, then we must raise STS instruction beyond the issue awareness level to include activities which build competence in issues, investigations and application of these issues.

4.52 What is the status of science education in India?

Kumar, Khandelwal, and George (1987) portrayed the current status of science education in India through a thoughtful analysis of both its system and policies. Areas considered in this report were education, academic environment, teachers, students, educational curriculum, examinations, and scientific research and development. The authors argued that, in a nation of 700 million people, science and technology education was of paramount importance if India were to make a serious attempt at reducing poverty and building a more prosperous nation.

4.53 What is an agenda for future research in science education?

Linn (1987) reported the results of a conference of leaders in science education research held at the University of California, Berkeley, January 16-20, 1986. The report described four themes that emerged from the discussions and made four recommendations intended to encourage the development of an integrated research base in science education. The themes included the following: (1) a growing consensus about the nature of learners; (2) a new view of the curriculum; (3) a new view of teaching; and (4) exploiting the new technologies. Recommendations were based on these themes and included: (1) establishment of centers for collaboration in science education; (2) expansion of opportunities for sharing information with others in science education, especially precollege teachers; (3) a better fundamental understanding of science learning; and (4) more emphasis on research in science education that reflects and responds to real instructional needs. Linn continued by stating that recent research into the cognitive processes involved in teaching and learning science had made it possible to integrate research, resource development, and instruction more closely. Now, methodologies should be developed to ensure more effective and timely use of research findings. Research should be conducted in real educational settings to provide new insights into the nature of cognitive and instructional processes while permitting study of the social and cultural factors that influence learning. Research using case studies and work samples to gain detailed, longitudinal understanding of the multiple interacting factors that influence learning should be conducted. Furthermore, it is critically important to encourage science learning among diverse populations and to meet individual needs as well. Researchers should be sensitive to this diversity when they design curricula and when they evaluate the effectiveness of their programs and recommendations. They should also monitor access to new technologies for all cultural and population groups and should identify ways to ensure access for all who desire it. Linn suggested that the science education research community should agree upon common goals and develop plans for action centered around the proposed recommendations.

4.54 What are the perceptions and opinions of the public concerning science education in the nation's schools?

Pogge and Yager (1987) conducted a survey among service club members concerning their perceptions of the importance of four science education goal clusters to students at four grade levels (K-3, 4-6, 7-9, 10-12). The four goal clusters were Science for Meeting Personal Needs, Science for Resolving Societal Problems, Science for Career Awareness, and Science as Preparation for Further Study. The survey was conducted among 5,400 club members in 1982 and 8,291 members in 1984. The results of the 1984 survey showed increases in perceptions of importance over the 1982 survey in all areas. The most dramatic increases were in Societal Issues and Career Awareness at all grade levels. As an example, in 1982 23% judged science education to be important for Career Awareness at grades 7 to 9, but this rose to 89% in 1984. The authors pointed to the rapid changes in attitudes toward science education and the importance for science educators to maintain current knowledge of public opinion.

Yager (1987) discussed an opinion survey of concerned citizens undertaken in 1976, 1980, and 1984, regarding the relative importance of various sources of information used by science teachers. Results reflected renewed interest on the part of the public in improved science education since a low point in 1976. Such changes suggested that the public was moving to new definitions for school science and to realizations of more appropriate sources of information than a single textbook. This movement was resulting in changes in perceptions concerning information sources for the science classroom, as indicated by greater importance of written materials over standard textbooks, the importance of human resources in addition to the teacher, and the recognition of the importance of direct student experiences as sources for information, ideas, and activities.

4.55 What is the present condition of science education in the nation's schools?

Reviewing the findings from the major science studies of the 1980s, **Yager and Penick** (1987) discussed the major crisis points in science education. These problems included: (1) existence of a mismatch between the science curriculum found in schools and that which students need and want; (2) nearly all science teachers (90%) emphasized goals for school science that were directed only toward preparing students for further formal study of science; (3) nearly all science teachers (90%) had a philosophical orientation only toward a specific discipline of science; (4) over 90% of all science teachers used a textbook 95%

of the time; hence, the textbook became the course outline, the framework, the parameters for student experience, testing, and a world view of science; (5) virtually no evidence existed with respect to the learning of science by direct experience; (6) much effort centered on writing textbooks, with little or no attention paid to the development of a science curriculum; (7) most instruction in science centered upon the mastery of unique words and terms with little attention given to their real understanding or use; (8) no evidence existed that science in its most basic sense was ever approached in school science; (9) laboratories were largely verifications of what students were told in class or what they had read in textbooks; there was no evidence that students ever experienced one real experiment throughout the school program; (10) ninety-percent (90%) of all high school graduates in the United States were not scientifically/ technologically literate; (11) the school was ineffective in influencing science interest, knowledge, or the further pursuit of either; (12) nearly all answer techniques and such lectures and question/answer periods were based upon the information that existed in the textbooks chosen; (13) few teachers appeared to be aware of any form of instruction other than direct teaching; few were aware of recent research concerning learning and instruction; (14) little relation existed between content preparation in science and success in teaching; (15) the effect of various teacher traits upon student learning accounted for less than 10% of whatever affects student learning; (16) stated goals for school science, other than those related to the disciplines of science, were seldom approached in an observable way or evaluated; (17) over 90% of the science education leadership emphasized the importance of continuing in-service programs for the future of science education; and yet, support for, leadership for, and availability of such programs declined significantly during the past decade; (18) most teachers (by observed practice, if not by stated philosophy) viewed science as knowledge to be mastered; they preferred the comfort of knowing what a course will be and what they want to impart to students prior to working with them; (19) over 90% of all science teachers viewed their goals for teaching in connection with specific content; further, these goals were static, seldom changing, and viewed as givens; and (20) science teaching was largely a matter of mastery of a new vocabulary; the number of new words and concepts presented were twice the number introduced when students learned a foreign language during a given year. Yager and Penick contended that cooperative efforts of elementary, secondary, college, university, and scientific communities were needed to resolve the crisis. They questioned whether it was proper to continue to focus energy and resources on programs for the gifted. Moreover, they suggested that it might be worthwhile to aim at preparing all people for citizenship, for living productive lives in an age controlled by science and technology, and for dealing with current problems, rather than focusing on just the few who will go on to become scientists. They suggested that this approach could be a way to attract some of the most talented and the most concerned students as future scientists and engineers. It offers potential to turn people on to science which, as it is now taught, may deter with too much rigor, too much mastery for the sake of mastery, too much abstraction too soon, too little relevance, too little meaning, too little perceived importance and usefulness. Moreover, Yager and Penick suggested that now is a most opportune time for coalition, for the power of effective understanding and leadership which can come only with a less arrogant view of the crisis.

Our final thoughts as we close the review of the literature in science education for 1987 focus on the national scene. We are dismayed, but not surprised, by the stark contrast between **Linn's** descriptions of a new consensus of the learner, a new view of the curriculum, a new view of teaching, and new uses of technology, and the picture painted by **Yager and Penick** of science teaching as it presently exists in the nation's classrooms. On the one hand, we view through the lens of the researcher the full, as yet unrealized, potential of science teaching and learning. Knowing the research literature, we also marvel at the increases in our knowledge of teaching and learning science that have been forged through research. We are reminded of what the early pioneers of the United States must have thought when they first viewed the Rocky Mountains from their wagons. Perhaps they considered how far they had already come and how much farther they had yet to go. But they also were confident of reaching their destination. We have similar thoughts and emotions, that researchers will continue to make steady progress toward a better understanding of teaching and learning.

On the other hand, we are jolted into reality by the general condition of science teaching and learning in the nation's schools. Moreover, the jolt continues, because we are overcome with the odd feeling that we have heard this before. Consider the Project Synthesis report, edited by **Harms and Yager** (1981), in which the authors used a discrepancy analysis model to examine the then present condition of precollege science education and to make recommendations for future action. Let us revisit an earlier day in science education through selected quotes from the Project Synthesis writers. Concerning biology education, **Paul DeHart Hurd** (1981) wrote:

> Goals of science teaching changed little in the twenty-year period 1955-1975, but currently they are in transition. The science curriculum improvement projects developed during the 1955-1975 period focused on goals related to the conceptual structure of scientific disciplines and their processes of inquiry. Throughout this period, the professional literature on science teaching tended to emphasize the need for a broader perspective for science teaching, including

> societal and cultural aspects, the interrelationship of science and technology, personal and humanistic foci, and decision-making skills. In practice, however, the emphasis has been on vocabulary and narrow course objectives (explicit statements of what is to be learned) as opposed to general goals (e.g., the nature of inquiry or of human beings). There is little evidence that the goals of the federally supported science curriculum projects were ever translated into instructional and testing practices, although these goals are advanced as justification for science teaching. Generally, teachers show little enthusiasm for teaching biology as inquiry. Instruction directs students to the 'right' conclusion and little heed is paid to developing and appetite for submitting beliefs to an empirical test. The curriculum is the textbook, and the objectives are those implicit in the text (p. 19-20).

Concerning physical science education, **Ronald D. Anderson** (1981) stated:

> It also should be noted that the purposes of the teachers in the schools are not always the same as specialists in either science education or general curriculum. Many of the aims that have been promoted by the leaders in the field over the last two decades are not really accepted by teachers. The emphasis upon inquiry and problem solving by science education leaders has been strong for the past twenty years (**Helgeson, et al.**, 1977, p. 175); yet, these concerns and the desire for increasing emphasis upon technological and social issues (**Helgeson, et al.**, 1977, pp. 182-183) are not reflected in school practice or in the views of teachers and administrators.....By and large science is not seen as particularly important except for the more highly motivated or gifted students (**Stake and Easley**, 1978, p. 12:20). Science literacy ceases to be a goal after grade 10 and science classes in grades 11 and 12 are designed for the high ability student (**Weiss**, 1978). In many ways it seems that senior high school science departments have given up on science as general education for all as their primary goal and instead have focused upon doing a quality job with more able students (p. 37-38).

Concerning inquiry in school science, **Wayne Welch** (1981) inscribed:

> It appears that many teachers and parents consider the primary purpose of science education to be preparation for the next level of schooling (**Stake and Easley**,

> 1978, p. 13:10). There seemed to be general agreement that 'the next level', be it junior high, high school or college, would require preparation in 'knowledge' rather than in inquiry skills. The knowledge nature of college entry exams (**Stake and Easley**, 1978, p. 4:8), the content of college courses (**Stake and Easley**, 1978, p. 13:1), and the intention of most students (70 percent) to go on to college (**Stake and Easley**, 1978, p. 18:106) all work together to convince parents, teachers and students that 'next year' knowledge will be more highly valued than inquiry skills. This knowledge emphasis, combined with the absence of equipment and poor preparation of teachers for inquiry teaching, has perpetuated the traditional pattern of "assign, study, discuss, and test" pervading most classrooms. This mode of instruction is, of course, efficient if recall of facts and definitions is the major goal of instruction (p. 62).

Concerning elementary science education, **Harold Pratt** (1981) wrote:

> The typical elementary science experience of most students is at best very limited. Most often science is taught at the end of the day, if there is time, by a teacher who has little interest, experience, or training to teach science. Although some limited equipment is available, it usually remains unused. The lesson will probably come from a textbook selected by a committee of teachers at the school or from teacher-prepared work sheets. It will consist of reading and memorizing some science facts related to a concept too abstract to be well understood by the student but selected because it is 'in the book' (p. 73-74).

Respectfully, we ask: Has anything changed in the nation's classrooms in the last 10-15 years? The data base for the Project Synthesis report was collected during the 1970s, yet a decade later, we must admit with regret that substantial, significant, permanent, large scale change in the way science is taught and learned across the nation has been painfully slow. We can point to isolated examples of schools and districts that have incorporated research knowledge and greatly improved the way science is taught and learned. In general, however, the bulk of the nation's schools seem to have made little progress in science teaching and learning. It seems that Newton's first law of motion holds even at this level, in that the body of the nation's schools "will remain in a state of rest or continue its uniform motion in a straight line, unless it is compelled to change that state by forces impressed upon it" (**Hewitt**, 1977, p. 651). The body of schools, in our judgment, is largely at rest.

We have a classic problem, as **Hayes** (1981) defined a problem, "Whenever there is a gap between where you are now and where you want to be, and you don't know how to find a way to cross that gap, you have a problem" (p.i.). **Hayes** (1981) maintained that to solve a problem, one must first understand the nature of the gap and then search for a means to cross it. Today, at the close of 1988, we possess a better understanding of the social, political, economic, historical, and academic factors that prevent closing the gap, yet that understanding is far from complete. Nevertheless, it is time for action, and **Linn** as well as **Yager and Penick** call for action. **Linn** argues for partnerships and **Yager and Penick** suggest that now is the time for coalition. If the scholarly community in science education is ever to have a large measure of success in defining and closing the gap, then it must go well beyond just conducting and disseminating research. Science educators must roll up their shirt sleeves and get their hands dirty in the social, political, and economic arenas beyond the community of scholars, and they must do so as a group and at a level far beyond present efforts. We are sure that some scholars will take offense with this position because, as individuals, they are already involved in such endeavors. Unfortunately, they are like the driver of a sub-compact car involved in a head-on collision with an 18-wheel semi-truck. The laws of physics predict very well the effects. We applaud the work of such people, but we lament that one person, or a few people, working in relative isolation will have but very limited effect. Other scholars will argue that such activities are the domain of other people and other organizations, that the job of a scholar is to produce knowledge. Others must put that knowledge into practice. Unfortunately, they are like the ostrich with its head in a chuck-hole in the street. It matters not whether the on-coming 18-wheel semi-truck swerves and misses or runs directly over the ostrich; the effect is the same. Rather, the scholarly community must begin to look for new vehicles, and they should be at least as large and sturdy as an 18-wheel semi-truck. The community of scholars must also understand that its job is not to create a head-on collision but to avoid one by participating in changing the present course of action in the nation's schools. Moreover, the participation must go far beyond present day levels, and the new vehicle will be assembled through partnerships and coalitions with people and organizations outside the community of scholars. It will be assembled by taking Schwab's admonitions seriously, that curricula which stand the test of time are curricula built not by the representatives of a single commonplace, but by the representatives of all commonplaces working together through coalitions and partnerships. Science-Technology-Society curricula that **Bybee**, **Rubba**, and others describe represent a viable solution. But the development and widespread implementation of such curricula will require much effort. For example, the National Science Foundation has required that publisher-developer partnerships be cemented prior to the award of curriculum development funds. But the widespread implementation of such curricula will require more complex partnerships. Such working groups are still either in an embryonic stage or exist only in the minds of their founders. It is time to get to work, as the future of our nation in the world community is at stake.

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